The Blast Furnace and Steel Plant

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The Blast Furnace and Steel Plant

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Keeping Up to the Pace

AT present, the manufacture of steel in its various forms is taxing the inventiveness of man as never before. This is due, to a considerable extent at least, to the persistent demands for a reduction in the cost of manufacture, and these demands are the outgrowth of intensive competition. Every department of our steel plants is subjected to the most searching scrutiny in order that any weakness in methods of production may be eliminated. There are also investigations conducted by research departments which have as their object the discovery of means whereby present processes may be improved.

That these efforts are gaining their objective is apparent to those who are conversant with steel plant practice as conducted a decade ago. Then there were no blast furnaces producing one thousand tons of iron in a day, there were no continuous sheet and strip mills, the quality of the steel from open hearth furnaces was not so closely controlled, nor was rolling practice in general of such a high order. Besides these advances, there have been many others, which, while less pronounced in effect, have been the means of greatly modifying practice.

To the credit of our plant managers, very seldom has any attempt been made to conceal a new piece of equipment or some modification of methods; but, on the contrary, they have evinced a commendable spirit of co-operation. Nevertheless, with the frequent changes that are being made it behooves engineers to be on the alert, as otherwise the company they represent may fall behind in the race. Keeping up to the pace not only requires persistence but also vigilance.

Design and Operation of Strip Mills[*]

Development of Strip Steel Demand in Germany and Evolution of Mill Equipment to Meet Requirements—Interesting Features of Design Are Brought Out and Production Figures Cited

Translated by R. W. DEIMEL[†]

IN the following a short survey will be given of the importance, producing capacity and layouts of various strip mills. In view of the fact that, first of all, plants of the "United Steelworks" have been considered, this report does not pretend to deal exhaustively with the subject of strip rolling.

Before the rolling of strip became a possibility, this commodity, which was chiefly used for barrel hoops, was forged under the hammer. As time went on, these forged hoops became inadequate in respect to outward appearance and accuracy. They were therefore cut from sheets. This method is still followed in some branches of fine mechanics, where bands of exceptional width are needed, which so far are not produced in the strip mill in Germany. At the present time, when strip up to several hundred meters in length and up to 400 mm. (15.748 in.) wide can be rolled, the market for strip has become a very broad one.

Formerly the weight of the finished strip coils was generally determined by the carrying capacity of a workman. By the installation of machinery the strip consuming industry has gradually progressed to heavier weights up to 400 kilos (880 lb.) per coil. The strip manufacturers have adapted themselves to the pace set by the consumers.

Trend Toward Wider Strips

The rolling of wider stock developed along similar lines as mentioned before, strip of about 400 mm. (15¾ in.) being now rolled in large quantities in Germany, in coils of about 400 kilos (880 lb.). The modern mills are able to go even higher in width if there is sufficient demand. Hence it follows that we could soon approach American standards if the market conditions were similar to those in the United States.

According to the latest reports published, the strip mills, or strip-sheet mills, in America are said to be able to roll so-called "strip-sheets" up to about 1200 mm. wide (47.24 in.) and 1½ to 2 mm. gage (.0591-.0787 in.) on continuous mills. Strips of 950 x 1.6 mm. (37.4 x .063 in.) have been rolled regularly for quite a number of years at the Weirton Steel Company plant. The sheet output of one such mill, according to information contained in the trade papers, in sheets of a fairly uniform description, is equal to that of all German sheet mills combined. For this reason, and in view of the cost of this mill (about $10,000,000), it follows that German conditions cannot always be compared with American conditions. In Germany it has so far not been possible to find a broad enough market for strip over 400 mm. (15.75 in.) wide.

The latest efforts of the strip consuming industries in Germany, in standardizing stampings and introducing mass production, point to the possibility that before long wider strip will be used on an increasing scale in place of sheet cuttings.

Fig. 1 shows the strip steel output, increasing year after year. It can be noticed that the increase in production, which set in before the war, has resumed its vigorous development during the later normal years. Last year for instance, the strip consuming industry has spent, according to the average yearly price lists, about 100,000,000 Reich Marks for cold and hot rolled strip. The increase in demand has almost quintupled during the last two years.

These figures show the important part played by the steel strip industry in the economical life of Germany, and it is worth while to mention several of the principal consuming industries. Manufacturers of bycicles, automobiles, cables, locks, stampings, clocks, conduit pipes, builders fittings, small arms, barrels, furniture fittings, welded pipes and general hardware use steel strip to a large extent. It may be interesting to know that a bycicle for instance is made 90 per cent of strip steel.

This compilation leaves out consumers using strip without further preparation, for baling, bundling, tieing, etc. One of the larger German strip mills alone produces a monthly average of 1775 tons of such baling hoops, ranging in width from 8 to 25 mm. (.315-.984 in.) equal to a total length of about 25,000 km. (15,620 miles). These figures however do not represent the total capacity of the plant, which for a number of years has produced only 56-60 per cent of its rated capacity, for lack of orders.

Specifications are Becoming More Strict

Simultaneously with the broadening use of strip steel came the more exacting requirements of consumers as regards quality of stock and range of specifications. Whereas during the last years prior to the war about 90 per cent of the raw material was Bessemer basic quality, this percentage has now dropped to about 70 per cent, the remaining 30 per cent being open hearth and special steel quality.

The requirements regarding tolerances have also become stricter. Although pre-war standards have remained unchanged, consumers requirements have become more exacting, and the plants have adapted themselves to the new trend.

Hot strip is generally rolled with an allowance in gage of plus or minus .1 to .25 mm. (.0039-.0098 in.) according to thickness and width. In width up to 80 mm. (3.149 in.) deviations of plus or minus 1 mm. (.0394 in.), over 80 mm. up to 150 mm. (5.905 in.) of plus or minus 1.25 mm. (.0492 in.), over 150 mm. up to 300 mm. (11.811 in.) of plus or minus 1.5 mm. (.0591 in.) and over 300 to 400 mm. (15.748 in.) of plus or minus 2 mm. (.078 in.) are permissible and customary.

Cold rolled strip has, as a rule, allowances within hundredths of mm. instead of tenths of mm. (1/100 mm. = .00039 in.). In width also, in case the usual

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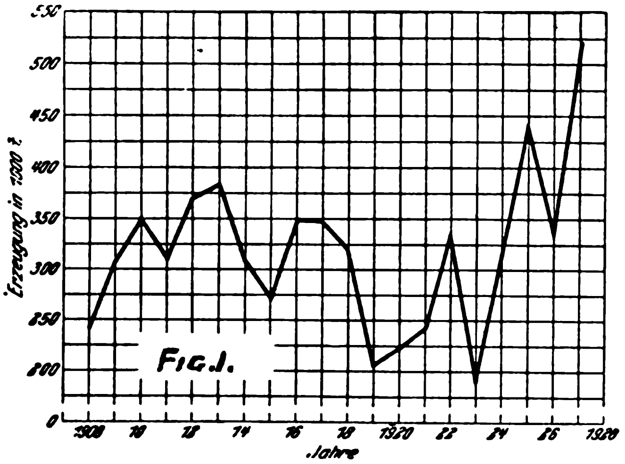
[*] Strip mills of the firm of Thyssen (Ruhr) and Dinslaken by Dipl. Engineer F. Winterhoff, Dinlaken. (Report No. 58 by the Rolling Mill Committee of the Verein Deutscher Eisenhuttenleute.)

[†] From Stahl und Eisen.



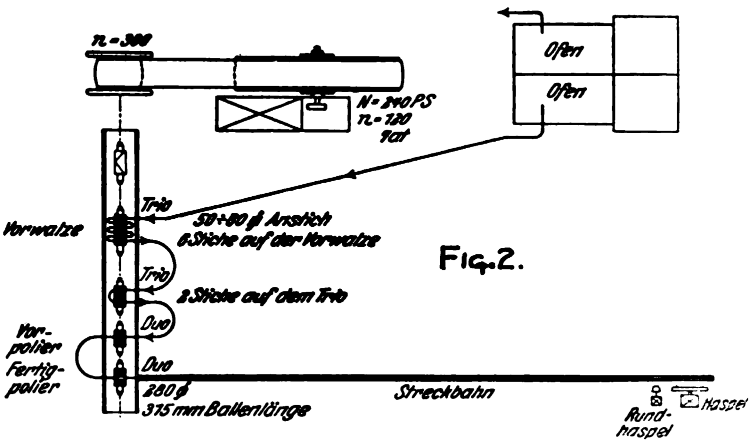


FIG. 1—Production of steel strip in Germany from 1908-1927. Erzeugung in 1000 t—production in 1000 metric tons; jahre—years. 280 mm (11.o23 in.) strip mill, built 1870-71.

FIG. 2—Mill built by August Thyssen. 280 mm (11.023 in.) strip mill, built 1870-71. n—expresses r.p.m.; N—expresses hp.; ofen—furnace; trio—three-high; vorwalze—roughing mill; vor-polierwalze—semi-finishing mill; fertig-polierwalze—finishing mill; duo—two-high; 2 stiche auf dem trio—2 passes in the three-high; 6 stiche auf der vorwalze—6 passes in the rougher; 50-60 anstich—50-60 mm first pass; ballenlaenge—length of body; streckbalm—run-out; rundhaspel—coiler for round coils; haspel—reel.

allowance of 1 to 2 mm. is inadequate, and accuracy of within some tenths or hundredths of mm. can be attained by trimming.

It has to be considered that in the hot rolling process a certain minimum thickness, according to the width of the strip, cannot be gone under. Through cold rolling the strip is further reduced in thickness, planished and brought to accurate measurements.

In the further development of strip steel it will be appropriate to establish definite standards for this class of material. In contra-distinction to universal bars, which are delivered with rolled edges, strip steel is supplied with natural mill edges up to a usual thickness of about 6 mm. (.236 in.). Only in special cases thicker gages can be supplied, with no guarantee for a good surface. Thinner strip for certain uses can be delivered with trimmed edges. There have been no limitations in width so far, in the one or other direction. It can be said however that the narrowest untrimmed strip is about 7 mm. wide (.275 in.) and the greatest width in Germany is limited to about 600 mm. (23.622 in.). In case of wider strip the rolls of the present mill equipment would tend to deflect owing to excessive pressure, resulting in uneven stock. This wider strip therefore would have to be rolled on special mills with two strong backing rolls, running in roller bearings, besides the two thin working rolls.

Evolution of Strip Mill Design

The strip mills which are in operation at the present time represent several distinct designs, the evolution of some of them dating back to the seventies. At that time, what they called "iron strip" which was to replace the strips cut from sheets, was a special product of the merchant bar mill. After steel strip was used on a broadening scale by the consuming industries, and the requirements became more exacting, special strip mills sprung into existence which started out with narrower strip up to 80 mm. (3.149 in.) wide.

In the following some characteristic strip mills of the "United Steelworks" will be referred to, and a brief summary given of their evolution and the most interesting features of their design.

The figures of daily output mentioned in connection with various mills are calculated on a monthly production basis, operating at full capacity. Production per shift or hour cannot be considered as proper rating for strip mills with a wide range of specifications, because these figures may fluctuate according to whether narrow, medium or wide strip has been rolled, and of what quality.

One of the first strip mills in Germany was built and put into operation during 1871-2 in Styrum (Ruhr) by August Thyssen. It was driven by a horizontal steam engine of 240 hp. Fig. 2 shows a layout of the mill. The arrow line indicates that the stock progresses through furnace, mill, finishing end, etc., in proper order. It further is evident that the mill is of the open type, roughing mill, semi-finishing and finishing mill in one line, with no differentiation of speed. A billet 50 or 60 mm. (1.9685-2.362 in.) was flattened by six passes in the roughing mill, and then given an additional edging and flat pass in the central three-high stand. The semi-finishing and polishing stand were of the two-high type, which reduced the stock to 20 to 40 mm. (.7874-1.5748 in.) width and 1 to 5 mm. gage (.0394-.1969 in.). The production amounted to 7 to 20 tons per shift, depending on sizes.

During the following years Thyssen could hardly produce as much strip as was asked for at that time, so he started out to build new plants. In these he turned the experience gained in the first plant to good account. It had been recognized in the mean-time that the rate of production depended on the velocity of the finishing mill and the speed at which the stock issuing from the rolls could be brought forward by hand. With the equipment then at disposal the elimination of the narrowest pass was possible only by increasing the velocity of the finishing rolls and by introduction of a mechanical run-out. By installation of a special drive for the finishing train, now taken out, and belt conveyors of high velocity for handling the strip the problem was solved. Prior to these innovations the strip issuing from the finishing rolls had to be grasped by a juvenile laborer, and according to the speed of rolling, carried forward so rapidly that it had no time to buckle. In this way the rate of production was limited by the speed of these men. Only by the aid of mechanical run-out the speed of the finishing mill, and thereby that of the entire plant, could be raised. It was intended not only to increase the number of rollings, but at the same time to prevent the cooling of long and thin bands between passes.

Fig. 3 shows a type of mill embracing these requirements. This mill is still in operation at Dinslaken. It was placed in operation in 1897, and has ever since been in operation without any alterations, to entire satisfaction. The three-high intermediate stand is still in the open finishing strand. In the last three-high housings rolling is only in one direction,

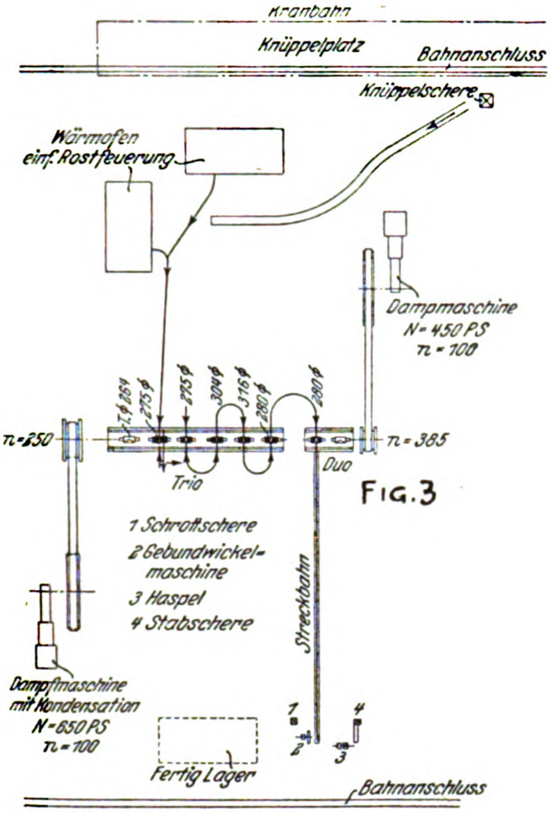


FIG.3

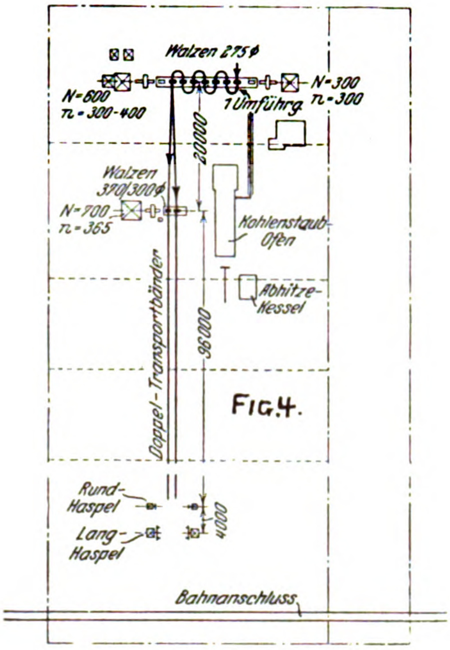


FIG.4.

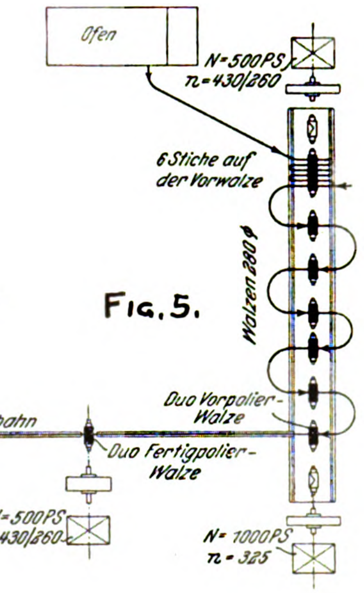


FIG.5.

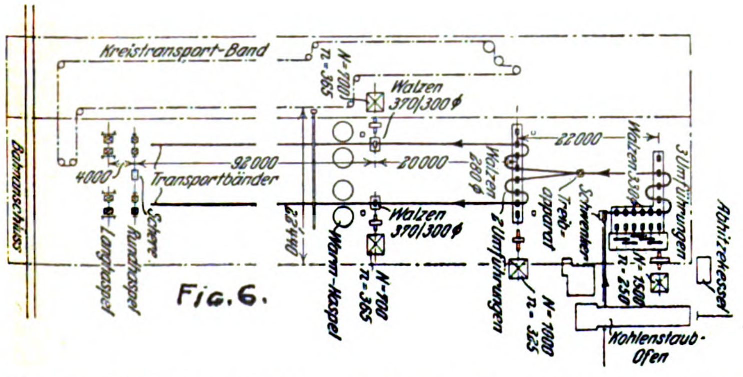


FIG.6.

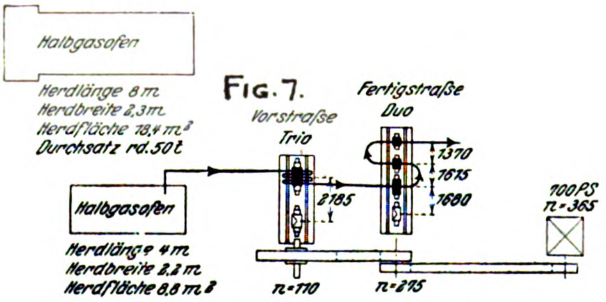


FIG.7.

FIG. 3—Strip mill built 1896. Kranbahn—crane track; knueppellagerplatz—billet storage; bahnanschluss—railroad siding; knueppelscheere—billet shears; waermofen einf rostfeuerung—heating furnace ordinary stoker fired; dampfmaschine—steam engine; duo—two-high; schrottscheere—cropper; gebundwickelmaschine—bridling apparatus; haspel—reel; stabscheere—bar cropper; dampfmaschine mit kondensation—steam engine with condenser; streckbahn—run-out; fertig lager—storage yard for finished goods; bahnanschluss—siding.

FIG. 4—Strip mill of the open type. Walzen—rolls; umfuehrung—repeater; kohlenstaubofen—powdered coal furnace; abhitzekessel—waste heat boilers; doppel-transportbaender—double-conveyor belts; rundhaspel—coiler; langhaspel—bridler; bahnanschluss—siding.

FIG. 5—280 mm (11.023 in.) strip mill. Ofen—furnace; 6 sticheauf der vorwalze—6 passes in the rougher; walzen—rolls; duo vorpolierwalze—two-high semi-finishing roll; duo fertigpolierwalze—two-high finishing roll; streckbahn—run-out; rundhaspel—coiler (for round coil); langhaspel—bridler.

FIG. 6—Semi-continuous strip mill, finishing strand divided. Abhitzekessel—waste heat boiler; umfuehrungen—transfers; walzen—rolls; kohlenstaubofen—powdered coal furnace; schwenker—switch; treibapparat—pusher; warm-haspel—reel for hot strip; transportbaender—conveyor belts; kreistransportband—circular transporter belt; scheere—shear; rundhaspel—reel; langhaspel—bridler; bahnanschluss—siding.

FIG. 7—Strip mill with roughing strand. Halbgasofen—semi-gas furnace; herdlaenge—length of hearth; herdbreite—width of hearth; herdflaeche—hearth area; durchsatz—capacity; vorstrasse trio—rougher three-high; fertigstrasse duo—finishing strand two-high.

with only one pair of rolls. The third roll is, similar to wire mill practice, used as a "blind" roll, meaning it serves as a spindle extension for transmitting power to the next stand. All further information can be gathered from Fig. 3. The stock used are billets from 50 to 70 mm. (1.9685-2.755 in.) square and 2200 mm. (7 ft. 3 in.) long. The average production amounts to about 40 tons per shift in widths of 25 to 70 mm. (.984-2.755 in.) and 1 to 6 mm. gage (.394-.2362 in.).

Improvements in Rolling Narrow Strip

In case of mills for the production of narrower strip, which had to operate at a higher velocity, the arrangement with one detached finishing stand was no longer sufficient to take care of the thin ribbons. This led to rolling two lengths of stock simultaneously, by dividing the finishing strand into two individual housings. Fig. 4 shows a mill of this description, open type. It will be seen that after the semi-finishing pass the stock is delivered into two finishing stands placed in line side by side. This mill can roll bands from 10 to 28 mm. (.393-1.102 in.) in minimum gage .85 mm. (.0346 in.). The production is correspondingly low and varies between 7 to 30 tons per shift, from billets 50 mm. (2 ft.) square, weighing 7 to 34 kilos (15.4 to 75 lb.).

Further experience taught the advisability of separating the two lengths of stock at a still earlier stage and make the roughing mill independent of the rest of the mill. This led, at the Muelheim plant, to the remodeling of a mill shown in Fig. 5, total arrangement shown in Fig. 6. It can be seen that the finishing strand has remained the same, but its mode of operation has been radically changed. Already after the ninth pass two bands of strip diverge in the center of the former finishing strand, are looped each through three housings in the directions towards the two ends of the strand, and after this they progress each through one finishing stand with special drive, arranged on parallel lines. This means that in the last four passes two bands are rolled simultaneously in separate stands. The old rougher has been taken entirely out of the main strand, to be replaced by a continuous roughing mill, with special drive, consisting of six stands in tandem combined with three three-high stands. After leaving the rougher the stock is cut by a shear, and, over an automatic switch, delivered to the two finishing strands. Only by this arrangement was it possible to attain productions in this mill up to 90 tons per shift. Stock in the shape of billets 50 to 75 mm. square (2-3 in.) is used, weighing 16 to 95 kilos (35-210 lbs.) yielding strip from 20 to 70 mm. wide (.787-2.755 in.) and .85 to 6 mm. gage (.0346-.236 in.) to be coiled hot or cold.

An older design in Fig. 7 shows that already prior to the remodeling of the last mentioned mill the rougher had been detached from the main strand. The latter had been developed as a three-high, called "donkey" among rolling mill men. Meanwhile better results had been obtained with continuous roughers, which led first to semi-continuous, and later to straight continuous strip mills. The separate arrangement of the rougher had developed out of the same idea as the detachment of the finishing stand out of the main strand; both evolutions starting at about the same time.

(To be continued)

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*Blast Furnace Practice in Natal**

Coke and Fluxes Are of Satisfactory Quality—Blast Equipment Designed for High Altitude—Operating Results Are Reviewed in Detail

By J. E. HOLGATE and R. R. F. WALTON

PART II

WHATEVER the quality of the ore may be, blast-furnacemen fully recognize that the successful operation of a blast-furnace depends, in a large degree, on the satisfactory quality of the fuel available for smelting. Up to the present time the Union Steel Corporation have not been in a position to manufacture their own coke, but have depended on the enterprise of certain colliery companies in Natal to meet their requirements. Speaking generally, these collieries have tackled the problem in a very thorough manner, and by establishing and maintaining a good quality of coke have assisted in a large way in the establishment of the pig iron industry in this province on a sound commercial basis. The price, however, is still too high (average, 21s. 6d. at the ovens), and it will be necessary to secure a material reduction in order to bring down the cost of pig iron to a level profitable for export in the world's markets. In the near future it is expected that the corporation will have a greater control over coke manufacture, either by a closer working arrangement with the present producers, or by erecting a coke-oven plant at the most economical point for the selection of coking coals and saving in railages.

Northern Natal possesses the only extensive areas of coking coal in South Africa, so far as is known at present. The Transvaal has rich coal-bearing areas, but mostly of a non-coking character. A number of collieries in the Transvaal have demonstrated by experiment that a coking coal exists, but in these instances it has been found that the coking coal only consists of a certain thin portion of the seam. For extraction this would involve selective mining. Up to the present one cannot see a commercial proposition in coke manufacture there, particularly as the average ash in Transvaal coal is higher than that in Natal coal.

The two areas in Natal which have been exploited on a large scale for coking coal are round Dundee and Vryheid. In the former the corporation is served by the Dundee Coal Company, who operate a battery of Coppee by-product ovens at Waschbank, about 50 miles from Newcastle.

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*Paper delivered at meeting of the British Iron and Steel Institute, May, 1928.

Average Analysis of Waschbank Coke (By-Product).

Coal Analysis	%	Ash Analysis	%
Carbon	86.54	Silica	46.20
Ash	11.05	Alumina	39.50
Sulphur	1.01	Lime	2.10
Moisture	1.40	Magnesia	0.95
Phosphorus	0.095	Ferric oxide	8.30

This coke, made from coal containing about 18 per cent of volatiles, is very strong and dense, and the question of breeze does not arise. On the whole, it has worked satisfactorily as a blast-furnace fuel.

Vryheid district produces beehive coke at several plants situated at different collieries round their coalfield. The average distance from Newcastle is probably 75 miles.

Average Analysis of Vryheid Coke (Beehive).

Coal Analysis	%	Ash Analysis	%
Carbon	86.59	Silica	49.00
Ash	11.95	Alumina	35.75
Sulphur	0.75	Lime	1.10
Moisture	0.68	Magnesia	1.09
Phosphorus	0.0055	Ferric oxide	9.45

The coals in the Vryheid district are eminently suitable for coke-making, and contain a somewhat higher percentage of volatiles as compared with Dundee. The beehive coke is of excellent quality, with a very low density combined with adequate mechanical strength. The yield from these ovens varies from 50 to 60 per cent, and the gases are, of course, a waste product. The ash is a little higher than the Dundee by-product coke, where the yield is probably 65 to 70 per cent, but the sulphur content is considerably lower. The phosphorus content is almost negligible, which would be an important asset in the manufacture of hematite iron from low-phosphorus ores, should this prove feasible at any time.

Comparison of Dundee (By-Product) and Vryheid Cokes—It has been established that the rate of combustion of the beehive coke is considerably greater than that of Dundee by-product coke, due entirely to its increased porosity. The mixture used at the furnace is about 50/50, which has proved very satisfactory, and full outputs of pig iron have been maintained with this proportion. With a preponderance of Dundee coke of denser character the furnace undoubtedly slows up through the decreased rate of combustion. Improvements however, are being effected at the ovens, at the corporation's suggestion, by charging the low volatile coal without compression. This, of course, may retard the output of the present coke-ovens, but for blast-furnace requirements it is essential to avoid excessive density, although for cupola practice it is often a good feature.

The low sulphur content of the Vryheid coke enables the furnace to carry a desulphurizing slag with a low ratio of lime to silica. This naturally results in a saving in the cost of flux per ton of pig. In our case it has been estimated that a reduction in the coke sulphur from 1 per cent to 0.75 per cent results in a saving of flux of 9d. per ton. That is, whereas a lime/silica ratio of 1:5 in the slag must be carried in the former case, it is possible to produce a similar iron with a 1:4 ratio in the case of all-Vryheid coke.

The furnace was started up and ran for about six months on limestone obtained from the Taungs deposit in Bechuanaland, the distance from Newcastle being close to 400 miles. The stone was of excellent quality but expensive, owing to the long railage. Subsequently experiments were made with a dolomite obtained for Natal Spruit, near Johannesburg, 180 miles distant, where a large deposit was exposed. Results were quite successful and a large contract was entered into, thus saving about 10s. per ton of flux.

The average analyses of these stones are as follows:

	Taungs Limestone	Natal Spruit Dolomite
Lime	54.30	28.60
Magnesia	0.35	18.75
Silica	1.45	1.75
Ferric oxide	0.25	......
Ferrous oxide	......	2.55
Alumina	0.15	0.25
Manganous oxide	......	2.60
Sulphur	Trace	0.003
Phosphorus	0.003	0.004
Loss on ignition	43.25	45.90

The presence of 2.60 per cent of MnO in the dolomite is an interesting feature, and the manganese appears to counteract any decreased desulphurizing effect of the MgO in the resultant slag. Without the addition of manganese ore, the manganese in our basic pig can be maintained at about 1.5 per cent, which is found to be a considerable benefit in the open-hearth.

Air

As this is the raw material used in the largest quantity, it is perhaps worth while mentioning the two main features regarding it:

1—The altitude of Newcastle being 4000 ft. above sea-level, it follows that allowance must be made in the design of any blowing unit to give the required volume at N.T.P. In our case it is necessary to increase the revolutions of our reciprocating blowing engines about 11.3 per cent to give the same weight of oxygen per minute as would be obtained at sea-level.

2—Although temperatures vary from 100 deg. F. maximum down to 22 deg. F. minimum, the air on the whole is fairly dry, the average moisture content being about 4.25 grains per cu. ft. in spite of very hot days in the summer, with frequent heavy thunderstorms.

Description of Plant

The blast-furnace has the following dimensions:

Height	70 ft. 0 in.
Bosh diameter	14 ft. 5 in.
Hearth	10 ft. 0 in.
Bosh angle	78 deg.
Throat diameter	10 ft. 0 in.
Bell	6 ft. 0 in.
No. of tuyeres	8 (5½ in. diam.)

The hearth is fitted with a steel-plated jacket with external water spray, while the bosh cone is cooled in a similar manner. The tuyere belt is fitted with three rows of copper cooling plates which have proved very efficient.

The capacity of the furnace is about 150 tons per day.

The filling arrangements consist of a long trestle gantry with concrete bunkers from which the different materials are drawn into the standard type of barrows for hand-charging. These barrows are drawn up by a steam-driven, double-cage hoist, and dumped into an ordinary type of bell and hopper. With cheap native labor available it was not considered advisable at this first stage to equip the furnace with a mechanical charger for the comparatively small output.

The iron is all cast in sand, the pig bed being traversed by a Morris crane of 10 tons capacity, which carries the beds of iron to a Lamberton pig-breaking machine from which the broken iron discharges into wagons for despatch or stock. An extension of the pig bed gantry also deals with a considerable amount of stock iron in combs.

The blast is supplied by two vertical reciprocating steam-driven blowing engines, compounded and equipped with an efficient condensing plant. Each engine is capable of delivering about 22,000 cu. ft. of free air per minute up to 12 lb. pressure at 60 rpm. Walker light disc air valves were fitted on the blowing cylinders after scrapping the original valves, which were unsatisfactory. These engines were originally used on the Rand gold mines as compressors, and were converted for our purpose by substituting larger air cylinders. Each engine is fitted with two air cylinders 60 x 60 in. Engine speeds vary from 50 to 60 rpm., according to requirements. It is proposed eventually to install a modern turbo-blower, but so far the existing engines meet all requirements.

There are four Cowper stoves (one erected since blowing in), 70 x 20 ft., with 7½-in. checkers, giving a heating surface of 42,000 sq. ft. per stove. The gas-burners are similar to the Bradshaw type with a central air-tube, while secondary air can be admitted through two side regulators. Blast temperatures exceeding 1400 deg. F. can be obtained, while a cold blast by-pass is provided or equalizing or regulating the blast temperature on the furnace.

The boiler plant consists of five gas-fired Babcock & Wilcox units, each of 250 hp., and generating steam at 160 lb. pressure. Special gas-burners were designed by Mr. A. K. Reese, which give a very intimate mixture of gas and air, while efficient combustion is always maintained by allowing the flame to pass through a checker firebrick wall in front of the tubes. This keeps incandescent and has proved a useful feature.

Great care was taken before starting to ensure a satisfactory water service, which would, if necessary, cope with a possible increase in the plant. The River Incandu, providing a neverfailing supply of good soft water, is situated 2,000 ft. from the engine room, which is roughly 40 ft. above the mean level of the river. The pump house at the river contains three Sulzer centrifugal pumps, each capable of delivering 1,500 gals. per minute through a 24-in. Hume reinforced concrete pipe into a sump at the engine room. The pump house can be hermetically sealed, with access only through the roof. This is necessary in case of heavy floods, when the river has been known to rise 18 ft. in a day. At the engine-room sump the water is distributed to the overhead furnace tank and to the various condensers by further centrifugal pumps. The return water then flows by gravity into the river again at a slightly higher point, so that a large reservoir with cooling towers is not necessary. For emergency use and for maintaining a constant level in the engine-house sump there is a pond on the property with a reserve content of 2,000,000 gals. of water, which can feed the system at any time. About 3,500,000 gals. of water are circulated through the works each day.

The electrical power for motors and lighting is generated by a vertical triple expansion Bellis & Morcom 500 kw., 500 volts d.c. set. The lighting system is supplied through a balancer set at 250 volts. There is a spare generator as a standby. As there is a surplus amount of blast-furnace gas it has been possible to drive the electrical machinery for an adjacent brickworks; also, at an early date it is expected to be possible to light the town of Newcastle and supply power to private consumers.

The slag from the furnace is removed in Dewhurst self-tipping ladles of 10 tons capacity each. This material has been found to make excellent railway ballast, and is also used in road-making and for concrete. At a future date the manufacture of cement on a large scale from the granulated slag is contemplated.

The works is equipped with a large engineering workshop and an up-to-date laboratory, which have been important factors in the successful operation of the furnace.

A small foundry is attached to the plant for the manufacture of railway chairs, utilizing native labor. Extensions are being made, and it is expected to meet all requirements of the railways in the near future.

Notes on Operation of Blast-Furnace Plant

Blowing-In—After the completion of all plant details, the blowing-in was effected in June 1926, the charging being as follows: First, 10,000 lb. of coke was placed in the hearth, followed by timber filling to a point 2 ft. above the tuyeres. Above this 36,000 lb. of coke blank was charged, followed by 54,000 lb. of coke blank with the limestone necessary for the two sets of coke. The ore round commenced at 600 lb., the coke round weighing 5,400 lb. throughout, and, on filling the furnace, the ore had reached 5,400 lb., or roughly one-half of the normal burden.

The following are the actual analyses of the materials used:

Coke: Waschbank By-Product.

	%
Silica	5.22
Alumina	4.17
Lime and magnesia	0.56
Ash	11.5

Ore: All Prestwick Outcrop.

Iron	48.50
Silica	7.00
Alumina	3.65
Lime and magnesia	0.75

Limestone: Taungs.

Silica	1.65
Alumina	0.18
Lime	53.95

As the stoves were cold, extra fuel was required to allow for any delay in heating up the stoves by gas, while naturally a little more margin was allowed in the primary stages of blowing-in than would be necessary at a corresponding plant in England, owing to lack of previous experience of South African materials and the comparatively raw staff who were to assist in the operations. It may be mentioned here that the management could only depend on one experienced furnaceman on each shift, namely, the foremen, who were imported. The native Zulu labor had still to be tested, but eventually proved very adaptable and hard working.

The furnace was started in the American fashion, using 5-in. tuyeres and applying light blast, without any interval for natural drafting. A small cast of foundry iron was obtained from the tapping hole with 24 hours, and the normal process was then followed, with successive increments of burden. The early casts showed 4 to 5 per cent of silicon, and the furnace was maintained on good foundry iron with 2.5 to 3 per cent of silicon for 10 days or so until a definite routine was established, when a basic iron burden was put on.

No difficulty was experienced in the filling and charging operations; the natives were well coached and quickly grasped the fundamental ideas, and an orderly system was soon developed. For a temporary period extra white supervision was necessary in connection with the operation of the hoist and distribution on the bell, etc., but this was soon withdrawn and the native organization came under the shift foreman direct.

More difficulty was experienced on the pig bed for the first week or two, as the natives, whose mentality in many respects resembles that of children, ran away at the first sight of molten slag and iron. Many changes had to be made, but they gradually became accustomed to the new conditions, and, by the exercise of patience and tact on the part of the management, became very efficient workers. As most of the Zulus can only work a maximum of six months in the year away from their farms, it became necessary to be continually training new native boys to take the place of those departing. This naturally threw more responsibility on the few leading white men in charge of different sections.

Within 14 days the furnace had attained an output of about 125 tons per day, and operating results proved quite satisfactory on the whole. Subsequently the output reached the scheduled capacity of the furnace, that is, 150 tons. In view of the restricted outlet for the product, however, it has not been considered advisable to maintain the maximum output of the furnace, so that the 5-in. tuyeres have remained. These will be replaced by 5½-in. tuyeres when occasion demands.

The first year's campaign has not run entirely smoothly, owing to many varying conditions, such as, (1) variations in the quality of the ore through the progressive phases of development at the mine; (2) mechanical troubles with blowing engines, which were however, satisfactorily overcome; (3) continuous training of labor, necessitating careful selection and rejection, with the main object of reducing labor costs to a minimum; (4) climatic changes, including frequent tropical downpours of rain, with occasional cloudbursts in the summertime.

The campaign lasted about 15 months, during which period 56,209 tons of iron were made, the output being restricted as mentioned above. The furnace was closed down on October 1, 1927, owing to the excess of stocks of pig iron, but it will resume operation after a period of 8 or 9 months. It is then anticipated that the full capacity of the furnace will be required for a more prolonged period, to meet the increasing demands for pig iron at the steelworks and foundries.

Smelting of Native Ores—For the first few months it was necessary to use practically all the oxidized outcrop from Prestwick, as described under raw materials. This contained 48 to 49 per cent of iron and was frequently very friable, producing an excessive amount of fines. The ore was very easily reduced, but the loss in flue-dust was at times rather high. Owing to the steep bosh of the furnace, however (78 deg.), hanging troubles were not experienced, and we are convinced that for smooth and economical operation the steep bosh is the main requirement even in comparatively small furnaces.

As the mine was developed the pure carbonate ore was reached, and this was mixed in gradually increasing proportions with the oxide ore at the furnace. As the smelting of raw carbonate ore was a rather unusual procedure in standard practice, and in most circumstances quite uneconomical, it was at first concluded that the ore must be calcined in the best way that could be devised. With the carbonate ore containing 40 per cent of iron, the actual content of CO_2 in the raw carbonate ore is roughly 31 per cent, while the free carbon content is 5 per cent. On complete calcination the free carbon is lost, as well as the CO_2, but there is a gain of about 5 per cent through final oxidation of the ferrous oxide to ferric oxide, thus reducing the net loss to about 31 per cent.

Assuming calcination to be 90 per cent efficient, a product should be obtained containing almost 58 per cent of iron, although SiO_2 and other impurities would rise in proportion. From the point of view of saving carriage, and the possible objections to driving off the large quantity of CO_2 in the furnace, it would appear that calcining at the mine is the only sound policy, thereby obtaining a concentrated material free of CO_2.

As a result of our experience, covering a long period of observation, our ideas on the subject have, however, been considerably revised. In the first place, the carbonate was calcined in open piles at the mines, using about 5 per cent of small coal. It was soon discovered that the 5 per cent of free carbon in the ore was more than ample to promote calcination without extraneous fuel. Several thousand tons were calcined in large heaps and put through the blast-furnace in admixture with the oxide ore. Although it was possible to reach an average of 56 per cent in the calcine, the process was objectionable for the following reasons:

1—Lack of uniformity of product. The greatest heat was generated in the centre of the heaps and caused excessive clinkering; the material was then difficult to size, and consequently proved refractory in the furnace. The outside layers were never completely burnt and thus a variable analysis existed throughout the heap, with consequent greater difficulties in burdening the furnace.

2—Deterioration in mechanical condition of the ore was accentuated by further repeated handlings. The hard, dense carbonate ore on being heated was split up into laminations which became more friable, and the ultimate proportion of fines becames appreciably increased. Under more precise control in closed kilns this difficulty might be overcome by allowing the lumps of ore to attain a stage in calcination where vitrification just commenced. But the problem is a difficult one, as actual clinkering must be avoided, and in open heaps, where the ore is in the slightest degree underburnt, friability results.

3—Expensive handling of the raw ore. A large amount of native labor was required for building the heaps, while refilling tubs and transporting calcine back to loading bunkers at the mine was no light task, though, of course, mechanical methods could be introduced eventually to save labor costs.

It was naturally concluded that certain advantages could be reaped by installing a system of closed kilns, but in the meantime small proportions of raw carbonate had been smelted in the furnace. The results were so encouraging that before installing kilns it was decided to experiment, as far as possible, with the carbonate, and obtain data, keeping in view the fact that a credit must be shown that would at least balance the extra railage cost of raw ore.

Before the end of 1926 development of the mine was proceeding well, but there were many engineering and mining difficulties to get over before the maximum tonnage could be guaranteed for daily requirements, while the stock of outcrop ore was almost exhausted. For an output of, say, 4200 tons of pig iron per month it was necessary to ensure a continuous supply of 10,500 tons of carbonate per month. In order to tide over the development period, and also the period of experiment on carbonate ore, it was decided to take a quantity of oxide ore (50 per cent iron) from Rodell's Farm (see above); this ore was taken purely as a temporary expedient, and for some months has constituted about 40 per cent of the average mixture, working quite satisfactorily.

The proportion of carbonate in the mixture was steadily increased from December 1926, when 33-1/3 per cent was functioning well, up to 50 per cent, and by June 66-2/3 per cent carbonate was yielding excellent results. The furnace drove quite smoothly on the whole, although the presence of some slightly bituminous coal from the upper seam at times caused periods of high pressure through a little wedging action in the furnace. The loss in flue-dust was decreased, and the gas was still highly combustible at the stoves and boilers in spite of an increased content of CO_2.

For a short period before closing down the furnace it was possible to make a run on all raw carbonate, and the results were very gratifying, particularly in respect to coke consumption. With all oxide ore the average coke consumption had been in the neighborhood of 2100 lb. per ton of pig. This was steadily reduced until for a short period on basic iron with all raw carbonate the low figure of 1734 lb. was obtained.

We are quite convinced that as a general practice raw carbonate can now be smelted with a consumption not exceeding 1800 lb. over a prolonged period, making allowances for maximum driving and any minor disturbing factors that arise. We have not yet reached final conclusions on all aspects of the subject, as it is desirable to make certain observations over a larger period; but the main principle has been established that the fuel saving, combined with the better mechanical condition of the ore as carbonate, and uniformity of operation, amply compensate for the adverse railage factor.

It has been evident that sufficient surplus heat was generated in the upper regions of the furnace to promote calcination without any loss of heat at the hearth, while the 5 per cent of free carbon is a fuel addition which, on the basis of 2½ tons of ore per ton of pig, is equivalent to—

$$\frac{5}{100} \times 5000 \times \frac{100}{86} \text{ lb.} = 292 \text{ lb. of coke per ton of pig.}$$

Principles of Carbonate Ore Smelting—Elaborating this subject a little further we should like to co-ordinate our operating experience with the present recognized theories of blast-furnace reactions, and any discussion or criticism that may arise from the statement we make can only be helpful in connection with a subject of undoubted general interest.

Unlike calcination in the open air, the ore resulting from the action of heat in the furnace shaft is a ferrous oxide—not Fe_2O_3. The process of iron smelting, speaking broadly, consists in the abstraction of oxygen from the oxides of iron and the melting of reduced iron sponge. It should follow, therefore, other things being equal, that the lower the state of oxidation of the ore, the less work the furnace has to perform, as the heat requirements for melting iron and slag in the hearth are constant. The lower oxides of iron of mineral formation, such as magnetite, occur in exceedingly dense masses, so that it is their mechanical condition which interferes with reduction, rendering them refractory. Although the extra oxygen from the higher oxide of iron involves an increased exothermic reaction with the carbon monoxide in the shaft, this means a greater quantity of CO which has to be generated previously at the tuyeres from coke—an expensive fuel.

If the work to be done in the shaft is reduced by having an ore in a lower state of oxidation, that work will be performed more efficiently. Less work, then, is thrown on the hearth, and a smaller coke requirement is sufficient for this.

Again, less coke in the hearth means less air to be blown, while, incidentally, there is less moisture to be decomposed, and the air can also be heated to a higher temperature owing to its reduced velocity through the stove.

Further economy in coke consumption is then arrived at by the further saving through the somewhat smaller weight of slag which has to be melted in conjunction with the reduced proportion of coke ash. Also, the fact cannot be ignored that the minimum weight of coke to be burnt per ton of pig promotes faster driving of the furnace, with a cutting down of radiation, conduction, and cooling water losses per ton of pig. One might express the final coke saving mathematically as the sum to infinity of a series of terms in geometrical progression, each saving in coke automatically involving a further saving because of reduced slag, higher blast heat, etc., these economies decreasing by a fixed ratio.

Summing up this theoretical consideration, it appears quite uneconomical to oxidize the lower oxide of the carbonate ore in a calcining heap or a kiln simply to reduce it again in the furnace.

TABLE I—Coke Consumptions Recorded During Campaign.

	Raw carbonate in mixture, per cent	Coke per ton of pig. lb.
Half-year ending Dec. 31, 1926..	25	2218
Half-year ending June 30, 1927..	52	2091
Three months ending Sept. 30, 1927	59	1995
August, 1927	58	1941
Sept. 15 to 30, 1927	100	1734

The coke consumptions recorded during the campaign are given in Table I. Although the results are naturally affected to a certain extent by many other variable factors, one can observe the progressive decrease in coke consumption as the percentage of carbonate ore increases.

It is also interesting to record the average analyses of blast-furnace gas taken over a series of determinations during normal working conditions at the furnace (see Table II). We commenced with all oxide ore from the Prestwick outcrop, and followed the investigation through, until, for a short period, we were able to observe the effects of working on **100** per cent carbonate. The estimations were taken with a Standard Orsat apparatus.

TABLE II

Variation in Gas Analysis with Increase of Raw Carbonate.

Raw carbonate in burden, per cent	Average gas analysis CO_2	CO	Total carbon oxides	Ratio CO/CO_2
Nil (all oxide)	10.9	27.9	38.8	2.56
33⅓	12.5	27.4	39.9	2.19
50	13.5	27.3	40.8	2.02
66⅔	14.45	27.5	41.95	1.90
100	15.0	27.8	42.8	1.85

It will be observed that in each phase the percentage of CO in the gas is practically constant. The CO_2, however, rises steadily, and the percentages of the latter when plotted graphically against the percentage of carbonate in the ore mixture show almost a straight line up to 66 per cent. It is intended, however, to follow up the investigation by taking a longer series of gas analyses of the higher proportion of carbonate, as there is much scope for ascertaining valuable information on the relation between the CO/CO_2 ratio and particular furnace conditions in our special practice. Up to a certain point it would appear that the extra CO_2 in the gas corresponds roughly by weight to the CO_2 in the carbonate ore.

There is also a steady average drop in the gas temperature as the percentage of carbonate rises in the mixture, other things being equal, until for the higher proportion temperatures as low as 180 deg. F. have actually been observed. As previously suggested, this is confirmation of a natural conclusion that, less oxygen being carried in with the ore to oxidize CO to CO_2 in the shaft (an exothermic reaction), less heat is evolved in the shaft, with consequent lower temperatures of the top gases.

Analyses of Pig and Slag—Using a mixture of roughly equal parts of Dundee and Vryheid cokes, the slag analyses given in Table III represent the best conditions of working for the corresponding grades of iron. For high-silicon irons it is usually advisable to use 1/3 Taungs limestone in order to keep the manganese down to 1.25 per cent. About 80 per cent of our output, however, is of basic quality for the steelworks.

TABLE III—Analyses of Pig Iron and Slag.

	Grade of iron Basic %	No. 1 Foundry %
Pig—		
Si	1.00	2.75
S	0.05	0.02
P	0.30	0.30
Mn	1.50	1.25
Slag—		
SiO_2	31.0	32.0
CaO	28.0	33.5
MgO	18.5	11.5
Al_2O_3	19.0	20.0
Ratio—$(CaO + MgO)/SiO_2$	1.5	1.4

Furnace Records for August 1927—These are given for one typical month, using a mixture of carbonate and oxide ores.

			Per cent
Output:	4152 tons	Basic pig	74
		Foundry pig	26

Average Analyses of Products.

Pig	%	Slag	%
Silicon	1.42	SiO_2	31.23
Sulphur	0.051	CaO	28.47
Phosphorus	0.31	MgO	18.36
Manganese	1.42	Al_2O_3	19.45
		S	1.75
		MnO	0.73
		FeO	0.55

Raw Materials Per Ton of Pig.

		%	Anal. of ore mixture (as recd.)	%
Carbonate ore	2697 lb.	= 58	Fe	43.7
Oxide ore	1931 lb	= 42	SiO_2	8.0
			CaO	0.30
Total ores	4628 lb.		MgO	0.20
			Al_2O_3	3.8
			Analysis of coke mixture	%
Coke	1941 lb.		Carbon	86.03
			Ash	12.13
			Sulphur	0.89
			H_2O	0.95
			Analysis of dolomite	%
Dolomite	1617 lb.		SiO_2	2.2
			$Al_2O_3 + Fe_2O_3$	3.5
			CaO	28.6
			MgO	18.7

Slag per ton of pig, 1500 lb.

Average blast pressure	9 lb. at engines
Average blast temperature	1160 deg. F.
Average gas temperature	310 deg. F.
Average engine revolution	51 per min.
Average air blown per min.	19,900 cu. ft.
Average moisture content of air	Three grains per cu. ft.
Weight of ore per rnd. (6 barrows)	11,344 lb.
Weight of coke per rnd. (6 barrows)	4,758 lb.
Weight of dolomite per rnd. (3 barrows)	3,963 lb.

Tuyeres and Coolers—During the campaign of 15½ months only one tuyere was lost, and no coolers; the furnace ran for 14 months without losing a single tuyere. The steep bosh, combined with a good water circulation, was no doubt largely responsible for this regularity. The feed pipes (1¼ in. diam.) for both tuyeres and coolers entered at the bottom with the outlet at the top, and this system prevented any possibility of the accumulation of sediment.

Stoves and Boilers—These maintained their efficiency for the whole period without cleaning, thanks to the efficient dust catchers. The fine dust which accumulated in the checkers was removed about every three days by firing a "gun" underneath the checkers. The boilers were taken off in turn for cleaning throughout about once every three months. The dust problem is, however, not a serious one, and with carbonate ore becomes negligible. There is thus no need, in our opinion, for any special system of gas cleaning.

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Sheet Steel for Automobile Bodies

The Normalizing of Sheet Steel Is Discussed and Its Development Reviewed—Mechanical Equipment and Metallurgical Control Described as Well as Resulting Properties of the Sheets

"AUTOSHEET"

PART VII

NORMALIZING is a form of annealing in which the iron base alloy is heated to some point above its upper critical temperature range, held at that point for a predetermined length of time and cooled to a temperature below its critical range in still air. While such a definition is general for all manners of normalizing, this discussion confines itself to such methods of normalizing as properly heat treat sheet steels for automobile body parts. Without doubt the subject should be the most interesting one of this series as very little has been written about it due to the rapid development of the art as applied to this particular product.

The normalizing of sheet steel has certain economical possibilities to the manufacturer which at the present time are secondary to the well established fact that it gives to the automobile industry sheets capable of taking the most difficult shapes used on the rapidly changing models with a minimum amount of breakage and scrap loss. Under such conditions the automotive industries are in a position to demand low breakage on most of their body parts fully realizing that a normalized sheet will, in most cases, satisfactorily make the stamping. This demand, in turn, has forced the leading sheet manufacturers to install normalizing equipment to meet competition. Indirectly their costs have been reduced as continuous normalizing has lowered operating expenses on the basis of the physical accomplishments in normalizing. This reduction in cost should continue to drop as this type of annealing is increasingly demanded and the furnaces used are mechanically improved.

Development of the Normalizer

The mechanical improvement in this type of furnace has advanced with great rapidity in the last five or six years—in fact so rapidly that those indirectly interested have not been able to keep pace with it. Therefore, before we discuss the general practice of normalizing sheet steel we shall briefly review some of these improvements which in turn should make us all the more appreciate the normalized sheet product which is taken so much for granted today.

While opinions will differ as to just who were the parties directly responsible for normalizing sheet steel the issue can be tactfully avoided in that, regardless of the party or parties, this treatment was indirectly the outgrowth of the continuous annealing of blue sheets. About 1914 the use of a continuous furnace for the blue annealing of sheets was in commercial use in several mills and as near as records and information will show, this was the parent of our present day normalizing furnaces. At that time the furnaces were 40 to 50 ft. in length in which the sheets passed through the furnace supported on brick rings which in turn were mounted on water cooled shafts. These shafts were about 18 to 24 in. apart and were rotated by means of endless chains, or a worm drive. Another method of carrying the sheets through the furnace was to run endless chains over discs. Attached to the chains were lugs or fingers 8 to 10 in. long on which the sheets rested and were thus carried through the furnace approximately this distance above the shafts. These methods of conveying blue annealed sheets were perfectly satisfactory at that time and in some plants these methods are still in practice for certain kinds of sheet.

However about this time the automobile trade began to demand "full finished" automobile sheets and as the models became more beautiful in design the parts became more difficult in shape and the same steel would not take the draw on these new body parts. At the same time competition in the automobile trade became acute and lower quotations were necessary. The manufacturer met the situation by adapting his continuous blue annealing sheet furnace to continuously heat treat his auto body sheets and found that not only were his costs cut but his product decidedly improved in quality through the refinement of grain structure. His problems from that time on have been mainly connected with mechanical improvements in his furnaces.

First and foremost it was found that the discs covered with brick scratched the sheets so they were abandoned for cast iron discs. Cast iron discs caused a so called "pitting" condition regarding which no satisfactory explanation has yet been made as to its exact source. To cover this case we advance a theory that the uneven surface of the disc causes it to collect some oxide from the sheet passing over it—the oxide adhering to the places where the sheet touches with the result that spots of oxide soon accumulate on the high spots of the cast iron discs. These high spots in turn indent the sheet while at high temperature (around 2,000 deg. F.) and thus cause a small depression or pit to appear after the sheet has been pickled. This condition of so called "normalizer pits" is still a source of grievance to a great many sheet mills. Cast iron discs have been discarded in many cases for wheels made of chromium, nickel and manganese in varying proportions which are better able to withstand the higher temperatures to which the furnace is subjected.

The use of water cooled shafts is still a problem as a high percentage of heat is wasted through this manner of keeping the shafts cool. Insulated shafts of the correct material and construction may overcome this. Furthermore the space between shafts has been reduced from 18 in. to around 12 in. which prevents the soft sheet from dropping down between shafts and subsequently clogging up the furnace. In such cases where the shafts are within 12 in. of each other the discs are staggered, thus allowing them to overlap. In many cases more discs are placed on the

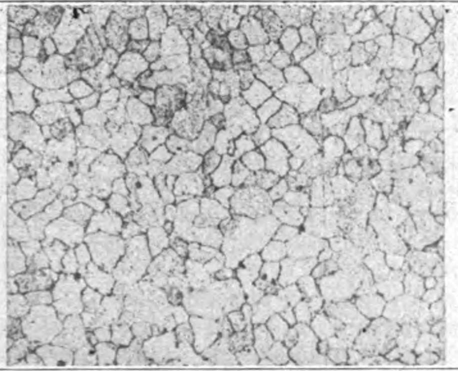

FIG. 1—20 gage 36 in. x 120 in. sheet heated to 1,800 deg. F. and cooled in normalizer. Note fine equi-axed grain structure.

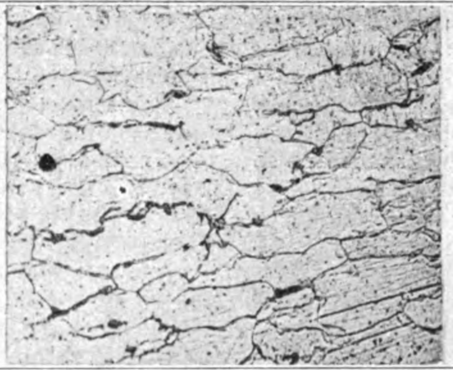

FIG. 2—Box annealed sheet out of a temperature of 1,600 deg. F.

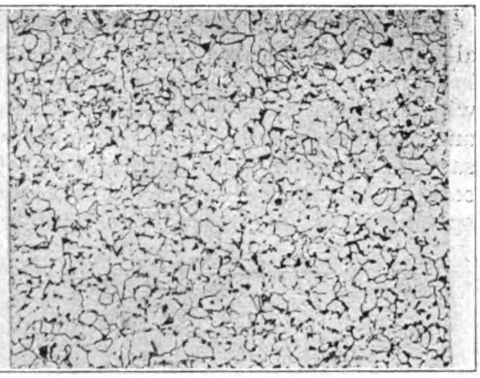

FIG. 3—Same steel as in Fig. 1 after being pickled, given one pass cold roll and box annealed at 1,300 deg. F. Note segregation of pearlite (dark spots) through slow cooling.

(100X etch, five per cent picric acid.)

shaft. Therefore the insulated shaft bearing more discs and in turn the closer spacing of the shafts brings a greater load to the main drive with the result that unless the furnace is a short one the chain drive has been abandoned for a substantial bevel or worm gear drive with the driving motor located in the center to allow for a minimum amount of torque. With the high cost of nickel or chromium disc wheels it can be readily imagined the necessity for dependable driving shafts, for a breakdown would mean the possible ruin of these discs in the high heat zone of the furnace before repairs could be made on the broken main drive shaft.

The selection of the proper fuel to be used was an experimental undertaking for a while with trials of coal, oil, producer, coke oven and natural gas and even electricity. Thus far the use of either coke oven or natural gas has preference due to the fact that these gases are clean and fairly constant in analysis, which indirectly aids the automatic control of these furnaces. Outside of the mechanical features for successful normalizing it is imperative that the furnace temperature and atmosphere be closely controlled. A reducing atmosphere is demanded as an oxidizing atmosphere will badly scale the sheets. Fluctuating temperatures in the various zones of the furnace, due to varying gas analysis, will also vary the structural quality of the steel. Both of these features are standardized in the use of a fuel of uniform quality under automatic control. Automatic control is practically necessary as a great many of the latest type of normalizers are from 100 to 150 ft. long and with so many burners on a furnace of these lengths it would be practically impossible for an operator to attempt the hand control of so many burners.

Having touched upon the outstanding factors present in the development of a normalizer for sheet steel let us build and operate a mythical sheet normalizer, give it a "successful" trial run and note the resulting physical, and microscopic properties of the sheet.

The Construction of Furnace

Our furnace will be 150 ft. long and 6 ft. wide to be divided into three temperature zones. Beginning at the end where the sheets are charged the first 33 ft. will constitute the preheating zone, the next 50 ft. will be the soaking zone and the final 67 ft. will be designated as the cooling zone. The preheat and soaking zones will have an arched brick roof of sufficient thickness and construction to prevent excessive radiation of heat so that practically all of it is absorbed by the sheets. The roof of the cooling zone will be lower and made of structural plate, lined with firebrick. The bottom of the furnace for its entire length will be insulated against the loss of heat.

The burners will be adapted for natural or coke oven gas and will be in a line about a foot and a half above the top of the sheets. They will begin about 20 ft. in from the charging end and run to the beginning of the cooling zone. These two rows of burners (one row to each side of the furnace) will be automatically controlled at two points thus giving us a constant temperature at two points representing two heat zones. One control will give us a definite temperature at the beginning of the soaking zone and the end of the preheat zone while the other control will establish a definite temperature at the end of the soaking zone where the maximum temperature in the sheet is to be maintained. These two points of control will be recorded by means of thermocouples inserted through the roof of the furnace at the above mentioned points. The resulting temperatures will be recorded on charts located near the two recorders which will indicate the fluctuation of the gas pressure or automatic gas regulators. The convenience of these gas pressure and temperature recorders allows the operator to carefully watch the furnace and to make changes if necessary. In addition, we will put CO recorders in about the central part of the soaking and cooling zones as it is imperative that for good results we maintain a reducing atmosphere in these zones.

Having put in the burners and controls let us next install the shafts and discs. The first 20 ft. of the preheat zone and the last 30 ft. of the cooling zone will carry semi-steel discs machined as round as possible and having a smooth rim surface over which sheets run. These discs will be mounted on shafts spaced about 15 to 18 in. apart. This space between shafts may seem rather wide but as the sheet enters the furnace it has sufficient stiffness to go from one shaft to the other without bending down between them and on the exit end of the furnace where the shafts have the same spacing, the sheets are sufficiently cool to have enough stiffness to prevent a similar bending. For furnaces running very light gages such as 22 and 24 gage the spacings should be closer.

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The remainder of the furnace i.e., part of preheat, all of the soaking and part of the cooling zones, carry heat resisting discs of chrome or nickel composition which in turn will be placed on shafts approximately one foot between centers. This close spacing is necessary as sheets in these portions of the furnace are so soft as to easily bend down between discs if their spacing were any wider. Every other shaft will carry 10 discs while those shafts between will carry nine discs, and will be so centered on their shafts that they will be half way between the discs of the adjoining shaft. In other words the discs will be "staggered" so that the sheet will run three or four inches over the top of one line of discs before the line of discs on the adjoining shaft picks if up. All shafts except the last 30 ft. of the cooling zone will be insulated against the high furnace heat by special constructed brick collars or by heat resisting steel collars filled with some heat resisting compound such as crushed silica firebrick.

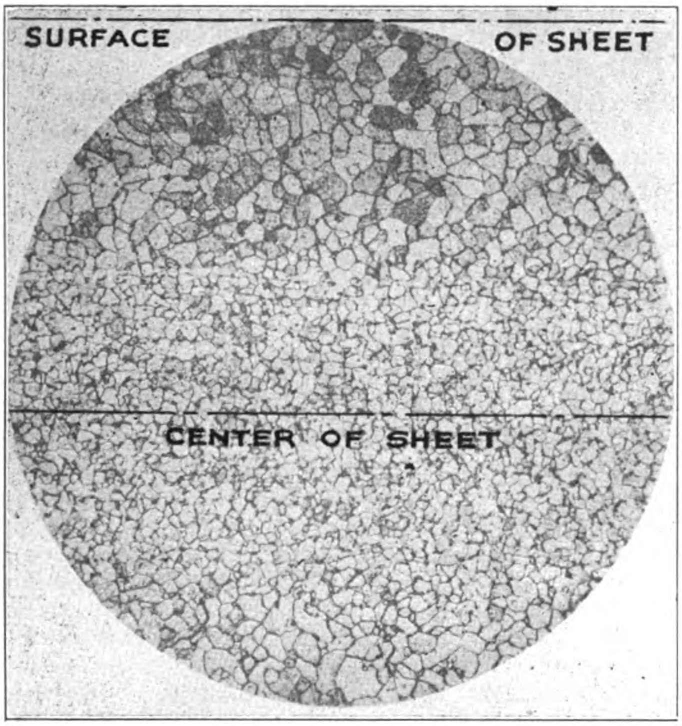

FIG. 4—Normalized sheet reannealed in box furnace at 1,400 deg. F. Note growth of grains near surface of sheet.

The shafts on the last 30 ft. of the furnace at the discharging end will be water cooled thus allowing us to not only keep this end of the furnace low in temperature but to reduce the temperature of the sheets as they are withdrawn from the furnace and piled. As will be presently seen, this cooling of the sheet is desired from a metallurgical standpoint as well as from a mechanical one.

In the building of this furnace we have completed its construction except for the motor and main drive which will turn the shafts and their discs. As the total weight of the insulated shafts and their discs will run into a high tonnage it will be necessary to carry a main drive shaft of sufficient toughness and strength as well as of sufficient diameter. In this 150-ft. drive we must overcome the friction of the bearings in which the shafts rest, the friction of the spur gears and the torque developed in such a drive so that the entire line of discs will all rotate not only at the same speed but will run smoothly and evenly. Furnaces of this length are very few at the present time, but overcoming mechanical features they give us the desired metallurgical results. Thus our problem at this point is a mechanical one and assuming that the motor for this drive is located in the center we will eliminate considerable torque while roller bearings on the main shaft will help to reduce friction and cause a more even rotation of the discs.

The speed of the motor and main drive will be such that by rheostat control the speed of a sheet passing through the furnace will be made to vary from about 20 to 60 ft. per minute, depending on the length of the furnace and the normalized structure desired. The sheet normalizers used for making automobile body sheet steel will vary in speed from 10 to 40 ft. per minute. A speed of 20 ft. per minute for a 20-gage sheet in a 100-ft. normalizer compares approximately with a speed of 30 ft. per minute in a 150-ft. normalizer depending of course on temperatures and the lengths of the various zones. This example merely illustrates the reason for our construction of a longer furnace—i.e., the initial high cost is soon compensated for in a greater production while obtaining the same physical properties.

Operation of the Normalizer

Having made our furnace to suit our metallurgical needs and taken all foreseen precautions in its construction let us now attempt a trial run. To avoid a lengthy discussion we must assume that the various speeds at which the sheets will pass through this furnace have been experimented upon, tested and approved by the metallurgical department after their comparison of the effect of resulting grain structure as influenced by the following factors.

Sheet steel of varying carbon content will greatly influence the grain structure of our steel but to eliminate that factor let us say that the carbon content will average around 0.10 per cent which will no doubt approximate the carbon content of the average normalized automobile body sheet. Another factor is that of the temperatures of the various heat zones but as these will necessitate more detailed explanation, let us set these at pretermined automatically controlled temperatures which eliminates for the time being an-

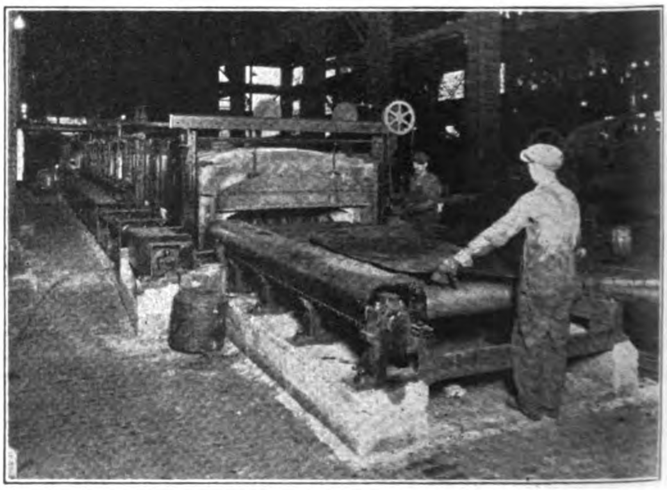

FIG. 5—Charging end of a normalizing furnace.

other contending factor. With the carbon content of the steel and the temperatures of the heat zones constant the speed of the sheet will vary according to its gage or thickness and its width. The length of our sheets will be a constant factor as they are fed single, end to end, into the furnace. If the widths of the steel do not vary to any extent in a day's run the operator, by watching his temperature recorders, can so adjust his gas pressure for each change in width that the factor of width can be eliminated.

This leaves the varying factor in the gage of the sheets and the usual procedure is to vary the speed of the drive in accordance with the gage of the sheet. To make ourselves clear let us repeat that with the close carbon range of the steel, the temperatures of zones automatically regulated and a slight opening or closing of the gas regulators offsetting the variation in width of the sheet, this leaves but one factor, which is the gage or thickness of the sheet, to be provided for directly by the speed of the discs. Thus an 18-gage sheet might run through the furnace at 25 ft. per minute and a 19-gage sheet at 28 ft. per minute and a 20-gage sheet at 30 ft. per minute, such speeds depending on the grain structure desired.

Let us now take a pile of 20-gage 36 in. x 120 in. sheets and follow their progress through this 150-ft. furnace. The analysis of the sheet shows the carbon to be 0.10 per cent, manganese .38 per cent, phosphorus 0.025 per cent and sulphur 0.017 per cent. A steel of this carbon content will have its (upper) Ac_3 point at about 1,600 deg. F. so it will be necessary that all portions of the sheet pass above this temperature in the heating zone.

As we will presently show it will be necessary to run this sheet through the furnace at a rate of 30 ft. per minute. This is better illustrated in Graph I which graphically represents the heat cycle for normalizing this particular sheet. The vertical dotted lines serve to visualize the demarkation points of the various temperature zones which are indicated at the top of the graph. The temperatures which are constantly maintained by the automatic gas regulators are shown by the crosses in circles, which indicate that the end of the preheat zone and the beginning of the heat or soaking zone will carry a temperature approximately 1,800 deg. F., while the thermocouple at the beginning of the cooling zone will register about 2,000 deg. F.

It must be understood that these are furnace temperatures only as determined by the couples located in the furnace roof. Our sheet temperatures at these two points, as determined by heat reflection tests, will approximate 1,600 deg. and 1,800 deg. F. respectively which are 200 deg. F. lower than the furnace temperatures. Furthermore the temperature of the sheet at the exit end indicates as it is piled, a heat ranging from 900 deg. to 1,200 deg. F. or an average of about 1,000 deg. Based on these known temperatures the solid black line shows the temperature of the sheet as it heats and cools in its progress through the furnace.

This heat cycle is plotted against the length of the furnace which gives us its position in the various zones together with its attendant temperature. Based on the predetermined speed of 30 ft. per minute for this gage 36 in. x 120 in. sheet we have also plotted the temperature against the time, thus showing at what time it is in the various zones and at the various temperatures.

Let us assume, from a metallurgical point of view, that the grain structure best suited for the automobile part intended, is microscopically shown in Fig. 1. Here, under a magnification of one hundred the ferrite and pearlite have crystallized into small equiaxed crystals far superior to the general grain structure of deep or extra deep drawing box anneal sheets as shown in Fig. 2.

If the grain structure as shown in Fig. 1 is what is desired on this size sheet, it has previously been determined that this structure is obtained by running the sheet through this 150-ft. normalizer in exactly five minutes or at a speed of 30 ft. per minute, and with the two automatic heat zones set for 1,800 deg. and 2,000 deg. F. as indicated in Graph. I.

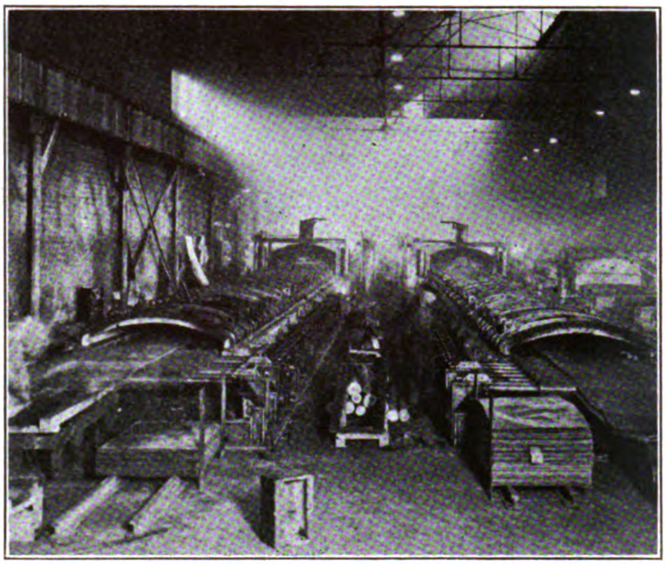

FIG. 6—Cooling zone and outgoing end of normalizing furnaces.

The formation of this structure and its attendant physical and microscopical changes, as the sheet progresses through the furnace, are worthy of a more or less detailed discussion for this is an example of the art of good normalizing as it is known today.

Preheating Zone

With the speed of the discs set so as to carry the sheet forward at the above speed and the temperature zones set to give us the correct furnace and sheet temperatures, a pile of sheets is placed alongside of the table at the charging end of the furnace (Fig. 5). This table is equipped with semi-steel rollers so that as the sheet is pulled from the pile by the operator it falls onto the table rollers and then is pushed by the hand under the charging door and onto the discs of the furnace.

The sheet is now in the preheat zone which, as we have previously mentioned, is 33 ft. long. If the speed is 30 ft. per minute we are going to move this sheet one foot every two seconds. One minute and six seconds later it has reached the end of the preheat zone where temperature recorders indicate a furnace temperature of 1,800 deg. F. and a sheet temperature of approximately 1,600 deg. F. which is about the upper critical heating point for a steel of this carbon content. Let us now see what has taken place in this one minute and six seconds of preheating.

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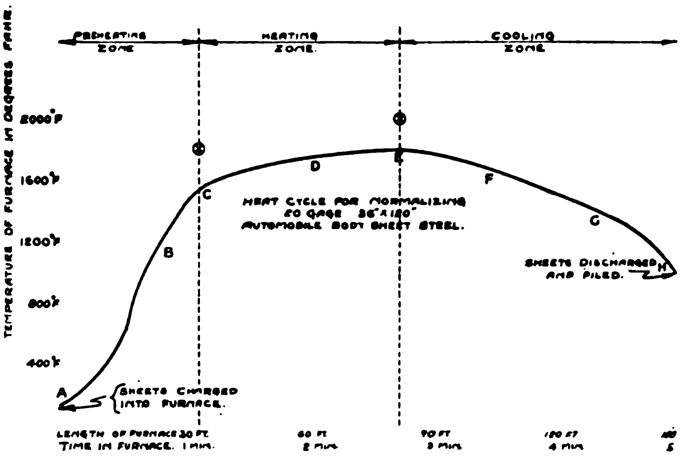
As the steel entered the furnace it began to absorb heat very rapidly in spite of the fact that the first 15 ft. of the furnace had no gas burners. The back pressure from the preheat and heat zones has raised the temperature of this first 15 ft. with the result that it is 1,300 deg. or 1,400 deg. F. just inside the charging door.

The laws of physics state that the rate of heat absorption between two bodies is proportional to the difference between the fourth powers of their absolute temperatures, and as there is a marked difference in the temperatures of the sheet as it enters and the furnace, the rate of heat absorption is very rapid at first gradually decreasing as the sheet temperature approaches the furnace temperature. Thus at point A in Graph I the sheet enters the furnace at about 75 deg. F. Coming into contact with about 1,400 deg. F. furnace heat at this point it absorbs heat very rapidly until it reaches the point B. The time elapsed is 45 seconds and the temperature of the sheet is now around 1,200 deg. F. From B to C (end of the preheat zone) occupies 21 seconds more but the rate of absorption is not so great as there is less difference between sheet and furnace temperatures, the sheet temperature now at approximately 1,600 deg. F. and the furnace at 1,800 deg. F.



Graph I—Heat cycle for normalizing.

In this heating of the sheet to 1,600 deg. F. practically all of the hot mill strains from hot rolling have been relieved (assuming that we start with a black sheet from the hot mill which is usually the case) and the constituents of the sheet change as follows:

As soon as the lower heating critical point (Ac_1) is reached, which for a 0.10 per cent carbon will be about 1,270 deg. F., the pearlite is bodily converted into austenite with the ferrite in the pearlitic formation changing to the gamma form of iron with the free ferrite still in the alpha state. As the heating continues more and more of this free or excessive alpha iron is converted to gamma form until we reach the upper heating critical point Ac_3 (1,600 deg. F.) at which point all ferrite is now in the gamma state and we have a solid solution of iron and carbon (austenite).

Heating Zone

However this Ac_3 point will in all probability come at a point near D in the soaking zone where all hot mill strains have been removed. As the actual rise in temperature of the sheet in this heating zone is only about 200 deg. F., about the preheat temperature, the length of time that the sheet is held in this zone is the factor in which we are now interested. This time factor really determines the size of the crystals and thus this zone is carefully watched with the time in this zone only long enough at the above mentioned furnace temperature to completely, as well as equally, heat the sheet to a predetermined temperature of 1,800 deg. F.

When the sheet has been completely relieved of strains it is probably within 100 deg. F. above its theoretical critical range and at which point the recrystallization of the steel takes place. This recrystallization from many nuclei or points imparts a fine structure for which we have been working and which we must now retain. All of this action has taken place between the point D of the heat zone, where as we have just said, the hot mill strains were all removed and the recrystallization started. The length of time the sheet is in the heat zone 50 ft. in length, is one minute and 40 seconds of which time 55 seconds was utilized to remove strains and start recrystallization and the remaining 45 seconds to give growth to the austenite grains.

Cooling Zone

Thus at the point E the furnace temperature is 2,000 deg. F., the sheet is approximately 1,800 deg. F. and the structure is very fine which we must now retain as much as possible. In this respect we are aided by three factors which help us to cool this steel to a point below the upper critical range and preserve the structure. First, the lower the carbon content of the sheet the more rapid the cooling may be from this point above the critical range to a point below it without appreciably affecting the ductility of the metal. Second, it has been found experimentally that bodies which absorb heat very rapidly are equally good radiators of heat. Third, the extreme thinness and large surface area greatly aid the eradiation of its heat.

As the sheet absorbed heat very rapidly in the preheat zone we can expect it to lose heat almost as quickly in the cooling zone providing we can keep a fairly wide range between the temperature of the cooling sheet and the temperature of this zone. This actually is not the case as the gas and heat from the heat zone flows back into the cooling zone. Thin walls and water cooled shafts in the exit end of the zone will, however, aid us and from Graph I it will be noted that the fall in temperature is greatly aided by the water cooled shafts in the last 25 ft. of the furnace (G to H).

The fairly rapid cooling under a reducing atmosphere from a sheet temperature of 1,800 deg. F. to 1,000 deg. F. takes place in the 67 ft. of the cooling zone in two minutes and 14 seconds, thus making a total of five minutes the sheet has been in the furnace.

At the point E the grains of austenite, continually growing, are beginning to be arrested in their growth from the surface of the sheet inward as the sheet enters the cooling zone. Due to the extreme thinness of the sheet this growth is quickly stopped which, as we will presently see has its effect on the physical properties of the sheet. However this physical effect is secondary and unimportant since we have attained a structure suitable for difficult automobile body stampings.

The cooling continues and at the point F we pass through the Ar_3 point or the upper cooling critical range. At this point the excessive ferrite in the steel changes from the gamma to the beta state and continues to precipitate out of the austenite until we reach a temperature of about 1,270 deg. F. (G) where it changes allotropically to the alpha state and the residual austenite changes bodily to grains of sorbite or pearlite with a grain size about the same as the size of the austenite grains. As previously explained pearlite is a mechanical mixture of one part of cementite (Fe_3C) and seven parts of ferrite.

If the cooling had been very slow the cementite would have combined with the ferrite in well defined laminated pearlitic formation but the cooling in the last zone of the normalizer does not allow all of the excessive ferrite to precipitate out. This fairly rapid cool causes the austenite, when passing through this lower critical Ar_1 point, to retain some of this excess ferrite, thus forming sorbite instead of well defined pearlite. This sorbite formation slightly increases the tensile strength and hardness of the sheet over that obtained by box annealing, but as previously mentioned, is negligible to the structure obtained.

The sheets, cooled to a temperature around 1,000 deg. F. and relatively free from scale due to the reducing atmosphere through which they have just passed, now pass out of the furnace. In most cases the sheets are not very flat and many normalizers use roller levelers at the exit end of the furnace, the sheets being piled after passing through the leveler. Fig. 6 shows the exit end of the normalizing furnace while Fig. 7 shows a general overall view.

In spite of precautionary measures to put through good sheets we are still faced with a slight pitting of the sheets by the discs as previously discussed. These pits are a series of small holes running in a line parallel to the motion of the sheet through the furnace and range in size from the point to the head of a pin which after pickling or cold rolling are very noticeable and objectionable. Most automobile body parts especially head lamps and radiators show up this defect very plainly after nickel or chrome plating and their presence is a menace to good normalizing today. To overcome this defect most normalizers pile the good sheet on top of another waster sheet known as a "dummy." This dummy sheet can be used over and over again but this is an expensive operation as more men are needed to handle the dummy sheets at the charging and exit ends, the sheets absorb almost as much heat as the sheet to be normalized and extreme care must be taken to prevent a scratching of the good sheet when placing or taking it on or off the dummy.

Results of Normalizing

With the elimination of such imperfect mechanical features of a normalizer as cause a scratched or pitted condition, the sheets from a metallurgical viewpoint should be up to our expectations based on the temperatures to which they were subjected and the time rate of their heating and cooling. To determine this a sheet of this trial is taken from the pile and a longitudinal microscopic specimen prepared along with various physical tests. The polished and etched (five percent pictric acid) specimen magnified 100 times (Fig. 1) indicates that the crystals are fine and thoroughly equiaxed, all approximating the same size—a structure that we were desirous of obtaining. In conjunction with this microscopic test, Table I shows the physical properties of this same sheet. This microphotograph (Fig. 1) together with its physical properties is worthy of comparing against the grain size and physical properties of box annealed sheet (Fig. 2). We therefore, have added to Table I a second set of figures showing this comparison.

It is at first surprising to note that in spite of a fine grained normalized sheet we have about the same elongation, ductility, reduction of original cross sectional area and Brinell hardness as that found in a fully annealed "dead soft" box annealed sheet. On a second glance at this comparative table we find that the Rockwell hardness, ultimate tensile strength and elastic limits are appreciably increased in the normalized sheet. This physical phenomena, as previously mentioned, is due to the rapid rate of cooling in the cooling zone of the normalizer which has precipitated sorbite instead of pearlite, thus increasing this Rockwell hardness, elastic and ultimate strength limits. However, in spite of this toughening effect of rapid cooling we are ahead of the game as our loss in ductility and elongation, as compared to the box annealed sheet, are slight and we have an excellent grain structure.

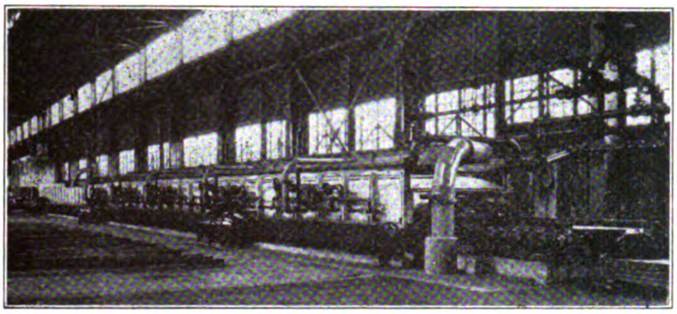


FIG. 7—Side view of long normalizing furnace.

The sheet thus far has been normalized only and possibly roller leveled and, following a pickling operation to remove any slight scale that may have formed on the sheet, it can be shipped for a great many auto-

TABLE I—Comparative physical properties of normalized only, box annealed only and normalized and box annealed automobile body sheet steels.

Treatment of steel Fig.	Normalized only 1	Box annealed only 2	Normalized sheet after pickling one pass in cold rolls and box annealed at 1,300 deg. F 3
Magnification (X)	100	100	100
Carbon content (% approx.)	0.10	0.10	0.10
Grain size	Very fine grains	Slightly grained	Slightly larger than Fig. 1
Tensile strength (Ultimate in lbs. per sq. in.)	53,100	38,800	47,600
Elastic limit (Pounds per sq. in.)	39,800	23,750	36,300
Per cent elongation in 2 in.	39.4	41.6	40.6
Per cent elongation in 8 in.	30.5	33.5	32.9
Per cent reduction of area	40.8	38.0	41.0
Hardness (Rockwell 1/16 in. ball, 100 kg. weight	50.5	29.0	43.0
Hardness (Brinell 500 lb.)	66.0	71.0	57.0
Ductility (Erickson in MM)	10.5	10.8	10.7
Ductility (Olsen in in.)..	.383	.388	.387

mobile body parts. Thus the continuous annealing of sheets by normalizing has eliminated at least one box annealing and produced in the sheet such properties that it is suitable for use on many parts.

One or more of the physical tests of Table I are usually practical in observing the operation of the furnace. Periodical microscopic tests are also advisable but for a check test on the normalizer it is discouraged in many plants due to the length of time taken up in carefully polishing and etching the samples. An occasional microscopic test and between the intervals of these, using physical means for determining the behavior of the normalizer, is probably quicker and more economical.

If, however, in spite of this fine grain structure obtained we desire a still softer sheet with a cold rolled surface, the normalized sheet is sent on to the cold rolls for a pass or two, thus smoothing the surface. For a softer sheet it is necessary to eliminate the sorbite which has raised the strength. To do this it will be necessary to box anneal this material, heating it to a point somewhere between the upper and lower critical temperature ranges for this .10 per cent carbon steel which is approximately within the range of 1,115 deg. F. to 1,562 deg. F. We have previously called this second box annealing a "process anneal" in which the slight strains from cold rolling can be relieved and the occluded hydrogen gas absorbed in pickling also removed.

The process annealing of a normalized sheet, however, becomes more important as it not only eliminates occluded gases and cold rolling strains but also this sorbite. As a general rule the process box annealing reheats the sheets to a point about 500 deg. F. below that temperature at which it was normalized. If the sheet in our normalizer reached a temperature of 1,800 deg. F. in the heat zone we will probably box anneal it around 1,300 deg. F. At this temperature we are again above the lower heating critical point and the sorbite has been converted to austenite with its ferrite in a gamma form. The remainder of the excessive ferrite is partially alpha and gamma iron as this sheet temperature is not quite half way to the upper critical temperature where it would all be gamma iron. The extremely slow cooling to room temperature from 1,300 deg. F. allows plenty of time for the austenite to reject all of the ferrite not to be used in the formation of pearlite. As the lower critical Ar_1 point is reached the austenite, in good eutectoid proportions, precipitates as pearlite in the laminated condition. Thus the slow cool has given us pearlite with a minimum hardness and has removed the toughness caused by sorbite from our normalized sheet. To better illustrate this second anneal we have added a third column of physical tests to Table I as well as Fig. 3.

Fig. 3 is the same steel as in Fig. 1 after being pickled, given one pass through the cold rolls and box annealed at 1,300 deg. F. In comparing the physical and microscopical properties of Figs. 1 and 3 it will be noted that the process annealing has appreciably decreased the hardness elastic limit and tensile strength and increased the ductility of the steel as determined by its elongation in two and eight inches. If this "process" annealing in a box furnace is carried over 1,400 deg. F. the slow cooling aggrevates grain growth (Fig. 4) near the surface of the sheet which is very undesirable.

(To be continued)

Metallurgical Advisory Board

Dr. John Johnston, director of research and technology of the United States Steel Corporation; C. A. Reinhardt, chief metallurgist of the Youngstown Sheet & Tube Company; Dr. A. J. Unger, manager of the research bureau of the Carnegie Steel Company, and Homer D. Williams, president of the Pittsburgh Steel Company, have been invited by President Thomas S. Baker to become members of the advisory board of the department of metallurgical engineering at Carnegie Institute of Technology, it is announced.

The advisory board, which is composed of about 25 steel company executives and metallurgists, is concerned primarily with the development of metallurgical research as now carried on jointly by the Carnegie Institute of Technology and the U. S. Bureau of Mines. Several important studies in ferrous metallurgy have been made under these auspices during the past few years. T. D. Lynch, consulting metallurgical engineer to the Westinghouse Electric & Manufacturing Company, is chairman of the board for the coming year.

Other members are: F. B. Bell, president, Edgewater Steel Company; Dr. Earl Blough, technical director, Aluminum Company of America; V. B. Brown, general superintendent, Allegheny Steel Company; C. A. Buck, vice president, Bethlehem Steel Company; Roy H. Davis, Pittsburgh; George H. Faunce, president, Pennsylvania Smelting Company; T. M. Girdler, president, Jones & Laughlin Steel Corporation; S. A. Grayson, president Jessop Steel Company; J. O. Handy, director of special investigation, Pittsburgh Testing Laboratory; C. W. Heppenstall, president, Heppenstall Forge & Knife Company; Charles R. Hook, vice president, American Rolling Mill Company; E. T. McCleary, president, Republic Iron & Steel Company; W. E. Moore, consulting engineer, Pittsburgh Electric Furnace Corporation; C. F. W. Rys, assistant to president, Carnegie Steel Company; Isaac M. Scott, president, Wheeling Steel Corporation; S. G. Stafford, Vulcan Crucible Steel Company; F. N. Speller, chief metallurgical engineer, National Tube Company; Kenneth Seaver, general sales manager, Harbison-Walker Refractories Company; J. C. Williams, vice president, Weirton Steel Company; and R. B. Zimmerman, assistant to vice president, American Sheet & Tin Plate Company.

For the coming year, it is announced, the advisory board has selected a program of five investigations in ferrous metallurgy to be made by research fellows under the auspices of the Carnegie Institute of Technology and the Bureau of Mines. An advisory board of coal mine operators and engineers, which occupies a similar relationship to the department of mining engineering, has selected six problems in fuel chemistry for investigation by six college graduates ranked as research fellows for the coming year.

C. H. Herty, Jr. on Editorial Advisory Staff

In line with the policy of Blast Furnace and Steel Plant to obtain, in an editorial advisory capacity, the services of authorities in the several branches of steel plant practice, another addition has been made to its staff. Dr. Herty is so well known that his activities need no comment. Our readers may look forward with pleasure to the benefits to be derived from his counsel.

International Study of Bituminous Coal

Fifteen Nations Are Represented in the Second Conference Which Offers an Important Program Including Technical Papers of Great Interest

TWELVE major topics for discussion at the Second International Conference on Bituminous Coal to be held under the auspices of the Carnegie Institute of Technology, Pittsburgh, Pa. November 19-24, 1928, are tentatively announced by Dr. Thomas S. Baker, president of the institution, and chairman of the congress. About 100 engineers and scientists representing 15 nations have already tentatively accepted invitations to speak or to send papers to the congress, and the number of speakers and delegates is growing daily.

Although the second international conference will be similar in purpose to the first congress held in 1926, preliminary plans for this year's meeting show that its scope will be considerably enlarged and the program will be more important and more international in character. The discussion of fixed nitrogen is one of the topics which will receive close attention. The liquefaction of coal, which was one of the principal subjects of discussion at the first meeting, will again occupy a prominent place in the deliberations. Low temperature distillation will be treated by representatives of at least a half dozen countries. High temperature distillation, power from coal, coal tars and oils, complete gasification of coal, origin of coal, coal washing, pulverized coal, catalysts, and the general aspects of the bituminous coal industry are other topics that will be considered.

Among the outstanding Europeans who are expected to attend the congress are Donat Agache, E. Audibert, Jean Bing, Emile Heurteau, Antonie Vonk, Paul Weiss, Henri Winckler, and Raymond Borr, France; Dr. Franz Fischer, Professor Fritz Hoffman, Professor F. P. Kerschbaum, Dr. Carl Krauch, Dr. Friedrich Bergius, Rudolph Pawlikowski, Professor Ernest Terres, Professor Dr. Glinz, Dr. J. E. Noeggerath, Joseph Plassman, Rudolph Battig, Dr. Karl Bunte, and Professor Fritz Frank, Germany; Lord Melchett (Sir Alfred Mond), Dr. Cecil H. Lander, Harald Nielsen, Colonel Lindemann, Dr. R. Lessing, and Edgar C. Evans, England; Commendatore Alberto Edeardo Bianchi, and Engineer Guardabassi, Italy; Professor Dr. Granigg, Austria; A. France, Belgium; Professor P. E. Raaschou, Denmark; Professor H. Kling, Poland; Professor George L. Stadnikoff and L. K. Ramsin, Russia. Japan will be represented by Professors Yoskikiyo Oshima and Chozo Iwasaki. Delegates will also come from Czecho-Slovakia, Canada, Norway, Spain, Chili, Roumania, Jugo-Slavia, and Bulgaria.

The economics of the coal industry will be discussed by Lord Melchett. Dr. Friedrich Bergius, Professor Dr. Franz Fischer, Germany; Andre Kling, and E. Audibert, France; Engineer Guardabassi, Italy, will deal with the subject of the liquefaction of coal.

Low temperature distillation will be treated by George E. K. Blythe, Dr. C. H. Lander, Harald Nielsen, Dr. E. W. Smith, England; Dr. A. Herz, Joseph Plassman, Professor F. P. Kerschbaum, Germany; Henri Lafond, Professor Paul Lebeau, Antonie Vonk, A. Leante, France; Professor Dr. Granigg, Austria; Professor Yoskikiyo Oshima, Japan; Professor Samuel W. Parr, Professor Alfred H. White, and F. C. Greene, United States.

High temperature distillation: Jean Bing, France; Professor Ernest Terres, Germany; Edgar C. Evans, England.

Power from coal: Dr. J. E. Noeggerath, Germany; C. Simon, France; A. T. Stuart, Canada; W. B. Chapman and Professor A. G. Christie, United States.

Coal tars and oils: Henri Winckler, France; Dr. L. Edeleanu and Professor Dr. Fritz Frank, Germany; and Gustaf Egloff, United States.

Gasification of coal: Dr. Karl Bunte and Dr. Alfred Pott, Germany; Paul Weiss, France.

Origin of coal: Professor George L. Stadnikoff, Russia; Dr. Chozo Iwasaki, Japan; Dr. Reinhardt Thiessen and Professor E. C. Jeffrey, United States.

Fixed nitrogen: A representative of L'Air Liquide Societe, France; Rudolf Battig, Germany, Professor Harry A. Curtis, Louis C. Jones, and Charles J. Brand, United States.

Coal washing: A. France, Belgium; Professor Dr. Glinz, Germany; Dr. R. Lessing, England; F. R. Wadleigh, Dr. F. W. Sperr, James B. Morrow, and Byron Bird, United States.

Pulverized coal: Dr. I. P. Goosens, Rudolph Pawlikowski, and Dr. P. Rosin, Germany; C. J. Jefferson, United States.

Catalysts: Professor A. Mailhe, France; Professor Hugh S. Taylor, United States.

Rubber from coal: Professor Fritz Hoffman, Germany.

Addresses not yet classified under these headings will be given, it is expected, by F. S. Sinnatt, England; Raymond Berr, France; P. E. Raaschou, Denmark; John Hays Hammond, Howard N. Eavenson, E. E. Slosson, Dr. Arthur D. Little, A. C. Fieldner, and Dr. H. C. Parmelee, United States.

The list of speakers, it is pointed out, will be considerably enlarged during the coming months. President Baker and his associates planning the congress expect to announce the final program details in October.

The members of the advisory board for the congress are John Hays Hammond, distinguished American engineer; E. M. Herr, president, Westinghouse Electric & Mfg. Company; Samuel Insull, capitalist; Frank B. Jewett, president of the Bell Laboratories, Inc.; Otto H. Kahn, capitalist; George E. Learnard, president, International Combustion Engineering Corporation; A. W. Mellon, Secretary of the Treasury; Auguste G. Pratt, president, Babcock & Wilcox Company; H. B. Rust, president, Koppers Company; Charles M. Schwab, chairman, Bethlehem Steel Corporation; W. C. Teagle, president, Standard Oil Company, New Jersey.

The Growth of the Inland Steel Company

Out of a Waste of Sand, Its Site Marked Only by a Railroad Tower House, the City of Indiana Harbor Has Risen, Based on the Demand of the West for Steel

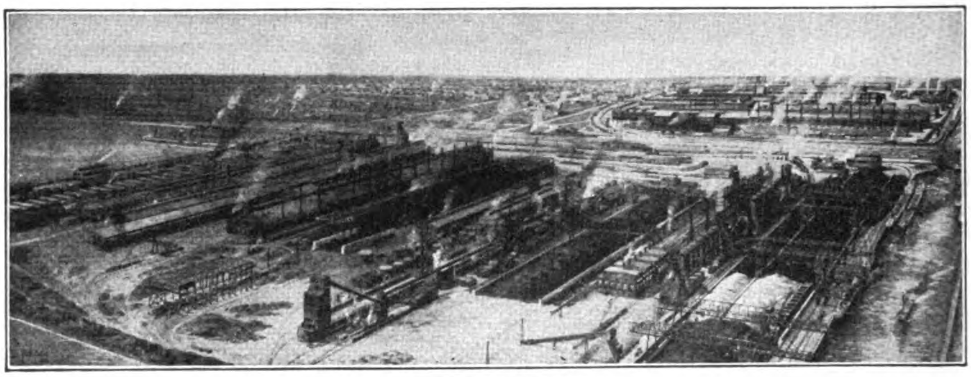
By J. L. BLOCK*

THE story of the growth of the Inland Steel Company's plant at Indiana Harbor, Ind., is the story of the transformation of acres of barren waste into one of the busiest manufacturing centers in the middle west. In two decades a desert has become a veritable dynamo of human effort and activity.

In 1901 Indiana Harbor did not exist and the territory now included in this city was marked solely by a railroad tower house surrounded by a vast expanse of seemingly useless sand. The nearest accessible points were East Chicago, Whiting and Hammond.

Selection of the Site

It was in this year that the Inland Steel Company purchased 50 acres of this land and built their original plant which included four open-hearth steel furnaces, a blooming mill, a bar mill, eight sheet mills and a jobbing mill. At this time Mr. G. H. Jones was president of the company, and Messrs. R. J. Beatty, L. E. Block and P. D. Block were vice presidents. The company remains under the same management today: Mr. L. E. Block being chairman of the board of directors and Mr. P. D. Block, president. Messrs. Jones and Beatty are both members of the board of directors.



Indiana Harbor Works

Operations were started in 1902 and 19,343 gross tons of steel ingots were produced before the year ended. The following year the total production was 62,088 gross tons.

Addition of the Blast Furnace Plant

The west needed steel and the Inland Steel Company grew and prospered. In 1907 the company met the need for pig iron by building its first blast furnace on an adjacent site overlooking Lake Michigan. At about the same time two additional open-hearth furnaces were constructed, together with a continuous bar mill and a sheet bar and billet mill. In 1910, when two more open-hearth, eight more sheet mills and another jobbing mill were added to the plant, the annual production of steel ingots was up to 303,090 gross tons.

The demand for steel continued to grow and with it came the steady expansion of the plant. The company acquired adjoining land. A plate mill, large structural, rail and blooming mills, a by-product coke plant, additional blast and open-hearth furnaces, and a bolt and rivet factory all took their places on the property.

Present Capacity Large

The open-hearth furnaces now number 26. There are four blast furnaces and coke is furnished by 204 ovens, with a complete by-product plant recovering the tar, benzol, ammonium sulphate and other products. The finishing mills now produce bars, shapes, plates, sheets, rails and track accessories of practically every size and shape.

The annual capacity of the plant at the present time is approximately 1,600,000 gross tons of steel ingots, more than 80 times the production of 1902. The company owns about 600 acres of land at Indiana Harbor, a portion of which has been devoted to a residential section for the employees. Over 7,000 men are now at work where the peaceful calm of inactivity reigned 24 years ago.

The plant stands today as a great servant of the middle west, a monument to labor, energy and foresight.

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*Assistant to the vice president, Inland Steel Company.

Chicago Mills Show Improvement

Backlogs begin to appear on the order books in the Chicago district and increased buying is indicated for the immediate future. Not only is an impending price advance a stimulation to buyers, but a real demand exists for all steel products and particularly in the automotive and implement trades. Building construction also is taking more tonnage, as are other lines so that the outlook of the last quarter is especially good.

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A Study of Sulphur in the Basic Process

Sources of Sulphur and Conditions of Its Elimination in the Blast Furnace Are Discussed with Special Reference to the Temperatures and Slags

By HAROLD A. GEIGER

SULPHUR in basic open-hearth steel comes from several sources, anyone of which may be the cause of the steel melting high in that element. Improper desulphurizing action may have been the contributing condition.

The three main sources of sulphur are: Pig iron (which in turn gets its sulphur from the coke, ore, and limestone of the burden), steel scrap, and fuel. Limestone in the open-hearth charge may contribute a little, and if large amounts of ore are charged as in run-off slag practice, the ore may contribute a little, but these amounts are usually negligible.

Sources of Sulphur in Pig Iron

Consider first the pig iron, a product of the blast furnace. In a survey of 35 blast furnaces in the United States, T. L. Joseph[1] found that for each ton of metal made in the coke practice, an average of 1.38 lbs. of sulphur were charged with the ore, 19.9 lbs. with the coke and 0.33 lbs. with the stone or approximately 92 per cent of the sulphur charged enters with the coke, 7 per cent with the ore and 1 per cent with the stone. Most of the sulphur is disposed of by means of the slag which carries off an average of 86.7 per cent of the sulphur charged, 4.63 per cent remaining in the metal and the balance passing off as SO_2. These figures are quite significant. This function of desulphurization that coke-iron blast furnace slags possess is very beneficial to the steel industry but on the other hand it is a costly function. The average slag volume on 35 of the above blast furnaces was given by Joseph to be 1107 lbs. per ton of pig iron. The quantity of sulphur to be eliminated effects not only the amount of slag to be carried off, but also its composition. The composition of the slag determines its fluidity or critical temperature. The average slag volume of six charcoal furnaces studied was given as 530 lbs. to a ton of metal produced. In charcoal practice desulphurization is not essential, hence there does not have to be maintained a ratio of bases to acids in the slag equal to 1.0, but we may have a ratio of bases ($CaO + MgO$) to acids ($Al_2O_3 + SiO_2$) as low as 0.4. If desulphurization were not essential, coke furnaces could carry as siliceous slags as charcoal furnaces and this would effect a tremendous saving in stone, resulting in a lower slag volume and lower critical temperature. These acid charcoal furnace slags carry off little more than 40 per cent of the sulphur charged.

From calculation based on the charcoal and coke slags, coke furnace slags require 300 lbs. of extra slag over and above that needed for fluxing the gangue and coke ash, to properly eliminate the sulphur. Joseph gives figures to illustrate the economic significance of sulphur in our iron industry. In 1921, 41,976,171 tons of coke were consumed in the pig iron blast furnaces. The sulphur in the coke cost the resources of the country approximately 3,000,000 tons of fuel in that year. He gives no figures for the saving of limestone but it is evident that the saving would be tremendous. The amount would be around 7,000,000 tons.

Slags and Slag Volumes for Desulphurization

The relation of the sulphur in the coke and its effect on slag volume he illustrated by graphical methods, and points out that if a large quantity of sulphur is to be eliminated, a large slag volume must be carried, and that on 35 furnaces a rather definite relation exists between slag volume and the percent of sulphur in the coke. Part of the graph may be presented as follows:

Sulphur in Coke Per cent	Weight of Coke Lbs.	Slag Volume Lbs.
0.7	950	1925
1.05	1100	2090
1.30	1320	2200

Kinney in his work[2], has done much to show us where, in the furnace, a good portion of the sulphur is removed. He found that by taking samples of material from the stack at various elevations from the stack line to just above the tuyeres, the metal at the lower level may contain 87 per cent of the silicon, 200 per cent of the manganese and 300-400 per cent of sulphur which will be present in the iron at cast. Thus, the critical region of the furnace for determining the final concentration of the sulphur is below the tuyere line. This means that most of the work must be done by the slag layer through which the metal drops when passing from the lower part of the bosh to the crucible. In this zone the iron, in a spray consisting of particles of varying sizes, drops through the slag losing sulphur by passing through it, or at the slag-metal interface, and tending to come to chemical equilibrium with the slag in the same respect as the other metalloids.

Desulphurization in the slag is accomplished by the following reaction:

$$(1) \qquad FeS + CaO \longrightarrow FeO + CaS$$

According to this reaction, desulphurization of the metal is promoted by high lime concentration, and is inhibited by higher iron oxide and sulphur concentration of the slag. The FeO in the slag may come from

(a) Oxidation at the tuyeres.
(b) Unreduced ore.
(c) Formation of FeO by the above reaction (1)
(d) Formation of FeO by reduction of SiO_2 with iron,
(e) Formation of FeO by reduction of manganese from MnO.

The iron oxide content of the slag is largely controlled by concentration of reactants and equilibrium conditions.

The reaction:

$$(2) \qquad FeO + C \longrightarrow CO + Fe - 36{,}600 \text{ cal.}$$

is endothermic and as the temperature is raised the FeO in the slag decreases. This occurs when the FeO in the slag and the carbon in the metal are at equilibrium. This agrees with blast furnace practice where hot furnaces give low iron-oxide slags and cold furnaces give high iron oxide slags.

This condition may be shown by means of physical chemistry. The absorption of heat in equation (2) would shift the equilibrium to the right, i. e., towards the reduction of FeO and would be expressed as follows:

$$(3) \qquad K_{Fe} = \frac{(Fe)\,(CO)}{(FeO)\,(C)}$$

and the constant will vary with the temperature. For an increase in temperature, the constant will increase for those reactions which will absorb heat and decrease for those which give off heat. Since Fe (metal) CO and C (coke) are taken as constant, K Fe increases with temperature accompanied by a decrease in FeO, therefore,

$$(4) \qquad K_{Fe} = \frac{1}{FeO}$$

The reduction of MnO takes place in a like manner:

$$(5) \qquad MnO + C \longrightarrow Mn + CO - 61{,}700 \text{ cal.}$$

and the constant is expressed as follows:

$$(6) \qquad K_{Mn} = \frac{(Mn)\,(CO)}{(MnO)\,(C)}$$

Since (CO) and (C) are the constant factors, the equation may be written:

$$(7) \qquad K_{Mn} = \frac{(Mn)}{(MnO)}$$

Conditions for Desulphurization

The exact mechanism of desulphurization is open to question. There are no exact records to show whether the greater portion of the sulphur is removed as the drops of iron pass through the slag or whether the elimination takes place at the slag-metal interface after the iron has reached the crucible of the furnace. It is plain to see that the calcium sulphide formed at the slag-metal interface would retard the reaction when a certain concentration of that compound was reached, and would eventually stop unless it diffused rapidly through the slag. The rate of diffusion of CaS through the slag would depend on:

(a) Slag viscosity.

(b) Concentration of CaS at the reacting surfaces and in other parts of the slag.

An experiment[3] was performed to determine the nature of desulphurization and to find out the effects of various slag compositions particularly those high in alumina, on the lowering of the sulphur content of the metal. In the first experiment, 100 grammes of molten metal (.13 per cent Sul.) was fed through a 1/32 in. hole dropping through a 10 in. layer of slag at 1525 deg. C. for 10 minutes. In a second experiment another batch of metal like that of the first was covered with a layer of slag and held for two hours. These experiments were repeated three times each time using one of the three slags in this table.

	CaO	MgO	Al_2O_3	SiO_2	Sul	MnO	FeO
(1)	47.10	44.6	44.6	9.3	.32	....	1.2
(2)	42.1	4.7	18.5	32.4	.01	....	76
(3)	10.44	4.7	26.12	31.6	.57	27.0	3.00

The sulphur was lowered from .13 to .01 per cent when the metal was dropped through slag No. 1. The same result was obtained in the case where the slag metal contact was made. Slag No. 2 reduced the sulphur content of the metal from 0.13 to .029 when dropped through the slag, whereas in the case of the slag metal interface reaction the sulphur was lowered to .022. Slag No. 3 removed smaller amounts of sulphur. It is difficult to draw definite conclusion from this experiment because of the great difference in the time factor. The results show that sulphur is reduced to the slag by both means and that a more thorough elimination is affected in the cases of slags Nos. 1 and 2. Examination of the slag composition would indicate that high alumina slags have a strong desulphurization action. McCaffery and Oesterle also found this to be the condition in their work. The nature of this function of alumina is not explained clearly in any publication. McCance[4] performed an experiment to investigate this action. He found that when molten aluminum at 850 deg. C. was added to an equal quantity of FeS at about 1250 deg. C. a rapid reaction took place forming a slag composed largely of Al_2S_3 and Al_2O_3 the latter resulting, so he claims, from the oxidation of the sulphide. It does not seem reasonable that metallic aluminum might have been reduced from the Al_2O_3 in the high alumina slags produced, yet it seems the only logical explanation for the removal of the sulphur by the slags containing a high per cent of Al_2O_3.

The Conclusions Reached by Johnson

Johnson[5] does not mention Al_2O_3 as being one of the desulphurizing agents in blast furnace operations, but gives the following:

1—Increase the lime content. This will provide additional free base above equilibrium conditions between the acids and bases, to unite with the sulphur of the metal to form CaS.

2—Increase the slag volume: This point has been discussed to some extent. The larger slag volume lowers the concentration of sulphur and thus alters the equilibrium of the slag in regards to that element. That is, a larger slag volume will carry away a larger amount of sulphur in proportion. Where an excessive amount of sulphur must be eliminated it is sometimes necessary deliberately to add to the burden, slag forming materials, and the necessary lime to flux them, so as to make a substantial increase in slag volume.

3—Increase the temperature: The effect of temperature on the reaction between FeS + CaO and their relation to FeO, has been discussed. Great care should be exercised however in this point, as a physically hotter furnace will produce an iron high in silicon. Silicon on the high side of basic iron specification, i.e., 1.25 per cent will produce a more silicious slag in the basic open hearth requiring more limestone to properly remove the sulphur in the bath. This gives a greater slag volume to contend with in the open hearth which is undesirable from a thermal standpoint. There is another undesirable feature to increasing temperature. By increasing the temperature the fuel consumption is increased which again increases the amount of sulphur to be eliminated thus producing a sort of a vicious circle for the steel operators to contend with. Increasing the lime content of the slag has this same effect as it increases the fusion temperature of the slag or its critical temperature, requiring more coke to produce this increased temperature.

4—Increase the fluidity. For actual working conditions a compromise must be set up between fluidity, high temperature, and basicity as the factors discussed in the first three points work together in desulphurization.

5—Increase the manganese content of the metal and charge.

Herty on Tuyere Zone Temperatures

Returning to point 3 valuable work has been published by Herty[6] in which he presents the results of an investigation of the relation between temperature, FeO in slag and sulphur in the metal with the following conclusions quoted below:

> 1—For a given furnace or for several furnaces working similarly, there is a direct relation between the average temperature at the tuyeres and the average concentration of the sulphur in the metal.
>
> 2—Similarly, the iron oxide (FeO) content of slags is controlled largely for normal working by the temperature in the tuyere zone.
>
> 3—In a single furnace during the period between casts, variations in temperature around the tuyere zone correspond to variations in the sulphur content of the metal during the following cast.

Some of the results may be taken from the graphs as follows:

Effect of Temp. on Sulphur Content.

Average temperature at tuyeres, deg. C.	Average sulphur in metal per cent
1660	.025
1620	.035
1565	.055
1500	.060
1455	.075

Effect of Temp. on Amount of FeO in Flush Slag.

Temperature in tuyeres above cinder notch, deg. C.	FeO, per cent
1665	0.12
1560	0.20
1465	0.26
1430	0.35

Michel[7] observed variations in silicon, manganese and sulphur during a cast and found these changes to correspond with fluctuations in metal temperature.

Laboratory Experiments with Slags

Further work has been done on the desulphurizing power of blast-furnace slags on a laboratory scale. Rankin and Wright[8] worked out the ternary system $Al_2O_3.SiO_2.CaO$ with the isotherms and melting temperatures of compounds and invariant points. They show that all blast-furnace slags are included in the limits $CaO.SiO_2$ (calcium bisilicate), $CaO.Al_2O_3.2SiO_2$ (anorthite), $2CaO.Al_2O_3.SiO_2$ (gehlenite and $2CaO.SiO_2$ (calcium mono-silicate). They also showed that a ternary system of gehlenite, bisilicate, and anorthite existed inside of the large silica-lime-alumina system, in which range practically all blast-furnace slag compositions fall. For example at point 40 per cent CaO, 30 per cent Al_2O_3, and 30 per cent SiO_2 the slag will crystallize out 20 per cent calcium bisilicate, 10 per cent anorthite and 70 per cent gehlenite. Feild and Royster[9] worked out the solubility of sulphur as MnS and CaS in slags and determined their viscosities based on the ternary diagrams of Rankin and Wright. These diagrams show the solubility lines on the ternary system for given temperatures.

McCaffery and Oesterle[10] take up the work of Feild and Royster and carry it to the point where the results may be directly obtained. The investigation of sulphur solubility was begun by determining the solubility of calcium sulphide in each of the minerals, anorthite, calcium bisilicate, and gehlenite, which constitutes the largest part of ordinary blast-furnace slags. Mixtures of chemically pure lime, Al_2O_3 and silica were made in the proportions present in anorthite and calcium sulphide. Calcium sulphide was added to these in definitely varying amounts and cooling curves were also worked out.

The system calcium sulphide-anorthite forms a eutectic with 6.00 per cent CaS melting at 1444 deg. C., with a probable compound containing 11 per cent CaS melting at 1500 deg. C. In a similar way the equilibrium of the system $CaS.CaO.SiO_2$ (bisilicate) was determined showing a eutectic of 2.00 per cent CaS melting at 1200 deg. C., and for gehlenite the eutectic contains 4.5 per cent CaS which melts at 1390 deg. C. and a probable compound containing 6 per cent CaS, which melts at 1460 deg. C. These determinations were made in a neutral or reducing atmosphere. Some of the results of their investigation are given in the following tables:

Solubility of CaS at Various Temperatures in Percentage of Total Melt.

Degrees C.	Bisilicate	Anorthite	Gehlenite
1600	40.00	42.00	44.00
1550	31.00	33.00	35.00
1500	22.00	24.00	27.00
1450	13.00	17.00	18.00
1400	4.00	17.00	10.00
1350	4.00	17.00	10.00

Likewise the equilibrium of the binary systems $MnS—CaO.SiO_2$, $MnS—CaO.Al_2O_3.2SiO_2$, and $MnS—2CaO.Al_2O_3.SiO_2$ is given as follows:

Solubility of Manganese Sulphide at Various Temperatures Percentage of Total Melt.

Degrees C.	Bisilicate	Anorthite	Gehlenite
1600	93.00	91.20	89.00
1550	75.00	67.00	57.00
1500	58.00	43.00	25.00
1450	41.00	18.00	6.00
1400	23.60	9.00	6.00
1350	14.00	.....	.....

Summarizing the results of McCaffery and Oesterle's work:

1—The effects of alumina in blast-furnace slags is to increase the solubility of the slags for calcium sulphide and to diminish the solubility of the slags for MnS.

(Continued on page 1208)

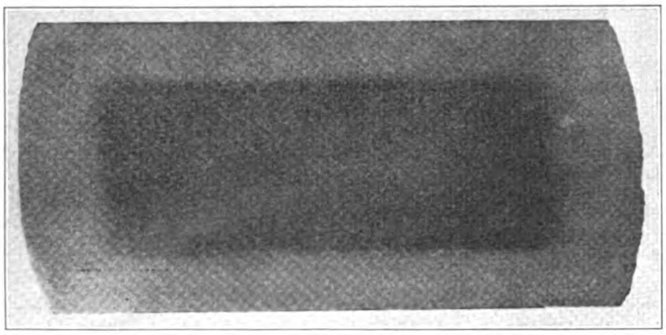
Purifying Steel with Sodium Compounds

Successful Application of These Much Studied Materials in the Manufacture of Steel Results in Improved Quality—Large Tonnages of Special Steel Prove Its Value

By J. R. MILLER

ABILITY to cast sound ingots free from inclusions, blow holes and dissolved oxides which will roll without cracks and show a clean surface in finished material as well as freedom from internal defects is the goal toward which the steel maker must work as never before. Increasing demand for sheets, seamless tubes, billets and bars for ultimate heat treated products, strip steel and, in general products demanding a high degree of quality have emphasized this necessity in recent years. Also the question of cost has entered into the general problem. It is becoming increasingly harder to divert steel unsuited for one purpose to a use less exacting and the rejection of steel due to imperfect quality is a serious item of expense. In addition good steel must be made at the same cost as, or at less cost if possible, than was formerly considered acceptable in the production of common grades.

Efforts in the direction of betterment of steel quality have been made in many ways involving desulphurization of the iron, selection of the scrap, increase in the manganese content of the iron, increase in the lime charge, careful methods in working the heats, care in the selection of fuels and the addition of various deoxidizers, more or less expensive, in the bath, ladle and even in the molds. Much attention and study have been given to mold design, temperatures and methods of pouring, treatment of the cast ingot, stripping and soaking pit furnace practice and to methods of rolling. After all allowance is made for all factors, the most important one is generally conceded to be the condition and quality of the metal that is put into the molds.



Hot deep etched section of sheet bar with purifier.

Among the additions or so called deoxidizers used in the reduction of the steel to its proper condition, sodium has received considerable attention both here and abroad. Efforts have been made in the past to utilize in some way or other the energetic properties of sodium in some cheap and practicable form, and the use of the carbonate has been directed by its cheapness and by the fact that it can be so combined as to be suitable as an addition in the purification process of steel manufacture. However, the solution of the problem of its utilization was not reached and results, until recently, proved not to be dependable when applied to tonnage practice.

Along these lines Dr. Charles T. Hennig* has made extensive experiments involving the production of steel in large quantities for the most particular requirements. He soon learned that the carbonate used alone mostly failed in a general way to produce the necessary reactions, and that small quantities of catalyzers were necessary to insure the positive action of the sodium in deoxidizing, and to secure a combination with the oxides, silicates, aluminates, sulphur and gases, so as to form a light gravity low fusion slag that quickly rises leaving the steel clean. The reactions so obtained give rise to an agitation facilitating the escape of gases. He has, therefore, prepared a mixture which he calls a "purifier" embodying these elements in proper proportions. On account of the low cost of the principal ingredient and cheapness of manufacture, it is an inexpensive addition.

Open Hearth Practice

In the open-hearth process, where hot metal is used, the mixture is added to the ladle at the blast furnace or mixer and charged with the accompanying slag into the furnace. But the main bulk of the mixture is added to the lime charge at the beginning of the heat. It is noticed, under these conditions, that the action of the bath is more prompt, so that less time is required to work the heat. Also not so much care is demanded in the selection of scrap. Where cold pig is charged, the mixture is introduced on top of or in with the lime. It is also used mostly without fluorspar to open the slag. If the heat is badly oxidized further addition of the mixture may be necessary.

Benefit is noted in some heats from an addition of the mixture to the ladle after tapping, but before the addition of ferromanganese, and it is possible to reduce the amount of ferro-manganese added thus effecting a saving in cost. Also less oxidizers, such as aluminum, silicon, etc., are required.

The amount of the mixture used depends upon the grade and condition of the metal and scrap. In actual practice this runs from two to four pounds per ton of steel.

Bessemer Practice

In the Bessemer process, the mixture is added to the ladle after the converter is tapped and before the ferromanganese addition is made. A low manganese content does not interfere with the good hot working quality of steel so made. When the mixer iron is off analysis and high in sulphur, the mixture is introduced into the transfer ladle as well.

Steel made by the addition of the sodium mixture is clean and dense, showing a better rolling quality and much less rejection. It also indicates a lessened

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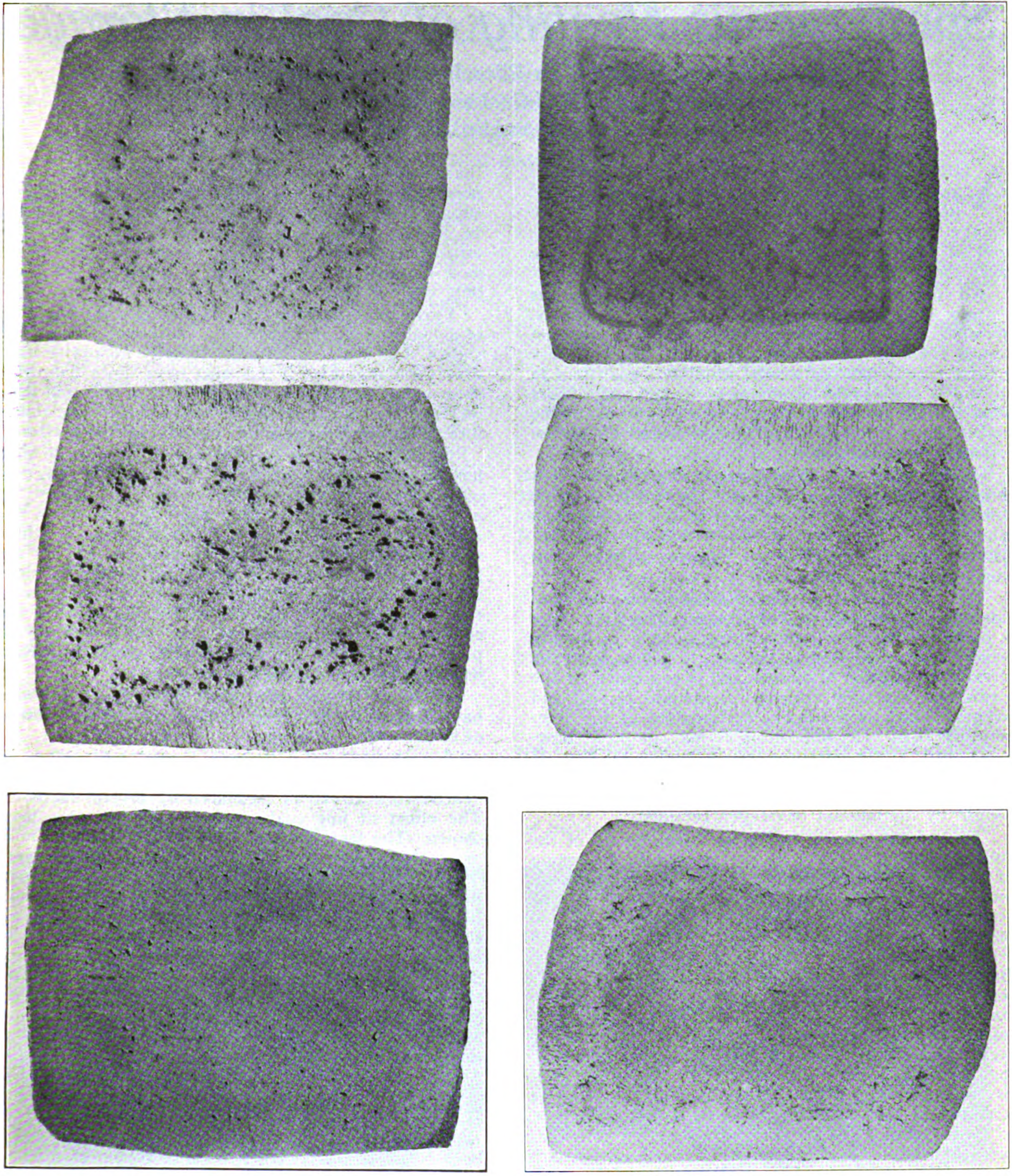
*Consulting metallurgist, Pittsburgh Plate Glass Company



Without purifier. **With purifier.**

Hot deep etched sections of blooms from top, middle and bottom portions of ingots of rimmed steel.

sensitiveness to the bad effects of sulphur, either residual or added. It helps to prevent checking in blooming and a minimum of chipping is required. The illustrations show the condition of the metal in large sections, compared with that in good ordinary practice, and speak for themselves as the benefit shown is very marked. Finished products present a clean surface, and an increase is noted in the ductility as shown in physical tests, as would be expected due to the soundness of the metal.

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Spontaneous Heating of Coal in Storage

Causes of Heating of Coal in Piles Is Discussed—Differences in Action of Various Kinds of Coal and Effect of Moisture and Ventilation Have Been Studied by Bureau of Mines

A GENERAL review of the results of chemical and physical research relative to the causes and prevention of the spontaneous heating of coal in storage has been published by the United States Bureau of Mines, Department of Commerce, as Technical Paper 409.

All coals but anthracite undergo some spontaneous heating, state Joseph D. Davis and D. A. Reynolds, the authors. The liability to self-heating is greatest among coals of lowest rank. One must therefore use greater care in storing a sub-bituminous coal than in storing a high-rank bituminous coking coal. More pains should be taken to prevent segregation of fine coal in the storage pile, and foreign matter should be excluded more carefully.

Oxidation of the coal substance itself is the main cause of spontaneous combustion; some of the organic constituents may contribute more to the heating than others, but it has not been shown that any one constituent exerts a preponderant influence to the exclusion of the rest.

The process of spontaneous heating may be considered to take place in two stages. The first stage is operative at room temperature as soon as freshly broken coal is exposed to the air. It begins with the physical absorption of oxygen and is continued by the formation of a solid chemical compound of coal and oxygen, which is gradually decomposed as the temperature rises. Decomposition is not complete, however, until the temperature reaches about 445 deg. F. This first stage of the process generates heat, but not as much as the second stage. The coal increases in weight by the amount of oxygen retained.

The second stage involves the breaking up of the solid compound of coal with oxygen and the formation of the final oxidation products—carbon dioxide, carbon monoxide, and water. With the Appalachian coals this stage begins to be appreciable at about 85 deg. F. and increases in intensity as the temperature rises. With lower-rank coals the beginning temperature is lower. Both stages of the process go on simultaneously, therefore, from about 85 to 445 deg. F. There is no sharp transition from one stage to the other; the curve showing the relation between duration of heating and temperature is continuous. The rate of heating increases logarithmically with the temperature; that is, no coal has as an inherent property a critical temperature at which there is a sharp transition from relatively slow to rapid heating. When the term "critical temperature" is used, it should be clearly defined as the temperature at which the rate of generation of heat becomes greater than its rate of dissipation under certain fixed conditions. For other conditions this critical temperature will be different.

For example, in a storage pile overheating usually starts in fine coal at a point about 6 ft. from the surface. If combustion ultimately develops at this point, one may regard the temperature of the coal when placed in storage as its critical temperature in so far as critical temperature is determined by conditions that prevail at this particular point. At any other point where conditions (fineness of coal, rate of air supply, etc.) are different the critical temperature will be higher. Results of laboratory studies in which critical temperatures of different coals are compared as a measure of relative ease of oxidation are valid only when the test conditions are strictly comparative.

Pyrite when finely divided can increase the tendency of a coal to heat spontaneously. Although it has been shown that coals containing virtually no pyrite have fires spontaneously, it has also been quite definitely shown that fine pyrite when present in the coal does increase the rate of oxidation. One would not, therefore, select for storage a coal containing fine pyrite.

Opinions differ as to what effect moisture in coal has on spontaneous heating. Probably the effect of moisture is determined by the condition of storage. If one could be sure of wetting only those parts of the storage pile where spontaneous heating would otherwise develop, he could very probably prevent it; the heat required to vaporize the water would be more than the oxidizing coal could supply. However, wetting down the surface of the whole pile changes the conditions of ventilation and may favor heating at points not reached by the water, where dangerous heating would not otherwise occur.

Chemical factors other than those touched above have little or no influence on the spontaneous heating of coal.

Laboratory studies have indicated what kinds of coal heat the most readily, and their relative tendencies to heat can be measured by several methods. The effect of fine coal, pyrites, etc., has also been shown. The fact remains, however, that all bituminous coals have heated in storage when conditions were favorable. It is believed, therefore, that the most fruitful studies of the future will deal with storage conditions. Work is particularly needed on the effect of air supply. For example, how should coal be stored to make sure that all parts of the storage pile will lack just enough air to support oxidation or shall have sufficient air circulation to carry off the heat generated?

Copies of Bureau of Mines Technical Paper 409, "Spontaneous Heating of Coal," may be obtained from the Superintendent of Documents.

High-Temperature Whitewash

Whitewash to be used in improving the appearance of brickwork in boiler settings and other places where it is subject to heat has been devised by Arthur, Mitchener and Withrow of the Ohio State University.

Prepare a thin slurry by stirring finely ground lime into five gallons of water. Slowly add, with stirring, 5 lbs. of salt, 5 lbs. of plaster of Paris and one-half pint silicate soda. Apply immediately with a paint brush to brickwork. Addition of the silicate too quickly or in excess will cause the slurry to become thick and useless as a paint.

Screening and Loading Domestic Coke

A Modern Plant that Prepares Sixteen Hundred Tons of Coke Per Day for Domestic Fuel—Weigh Hoppers Reduce Loading Time

By N. L. DAVIS*

THE problem of increasing the local market for domestic coke is of interest to almost every operator of by-product coke ovens. A description of the methods adopted by a large concern in the middle west that have proven profitable is here given.

A carefully prepared preliminary survey of local conditions uncovered the following facts:

(a) The average dealer can not afford to waste the time required for his truck to stand in line waiting to be loaded.

(b) The small dealer prefers to fill his orders as he gets them rather than carry a stock. Generally his orders run in one or two ton lots of the various sizes. His trucks are usually large, fitted with partitions, and he can deliver orders for two or three sizes with one loading. However, each size must be weighed separately, which causes a considerable waste of time, which he cannot afford particularly when the loading is congested.

(c) He prefers not to receive coke in carload lots because it then must be unloaded to storage and reloaded to trucks. This handling causes breakage and costs money.

(d) A seven-ton coal truck body holds only four tons ot coke; therefore, a greater delivery cost is necessary for coke than coal.

(e) The combination of facts (a), (b), and (c) resulted in prices to the consumer that were too high; a lowering of the quality of the coke; and a tendency toward a decreased demand for coke as a domestic fuel, in spite of expensive advertising campaigns.

(f) Storage and reclaiming of a large percentage of the tonnage became necessary. High handling costs and losses due to degradation had to be charged off.

(g) Car shipments to more distant markets resulted in reduced prices at the shipping point.

(h) The demand for a fine fuel prevailed if handling and degradation losses could be cut enough to make an attractive proposition to the domestic consumer and dealer.

Knowing of course that a better margin of profit lay in increased locally disposed of tonnage, an analysis of the existing conditions outlined above indicated that the adoption of the following measures would go far to correct the situation:

Stabilize prices.

Be prepared to vary the coke sizes quickly and cheaply to suit the demand.

Quickly load trucks as well as railroad cars.

Reduce degradation.

Reduce machinery maintenance costs.

Reduce labor costs.

Interest the local dealers.

Co-operating with the coke company's management and engineers, the Link-Belt Company designed, manufactured and installed the present installation, which was completed in September 1926. The features embodied in this installation that are of particular interest because of their departure from orthodox practice

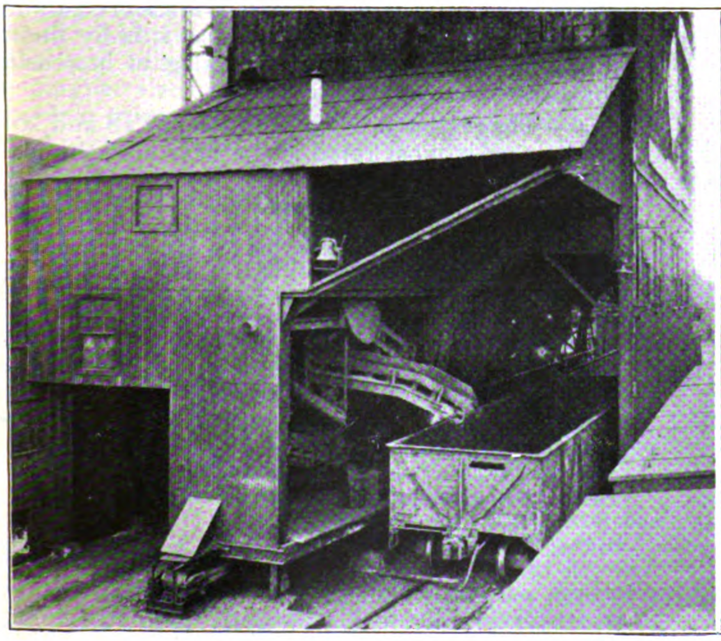

FIG. 1—Domestic coke house and method of loading railroad cars.

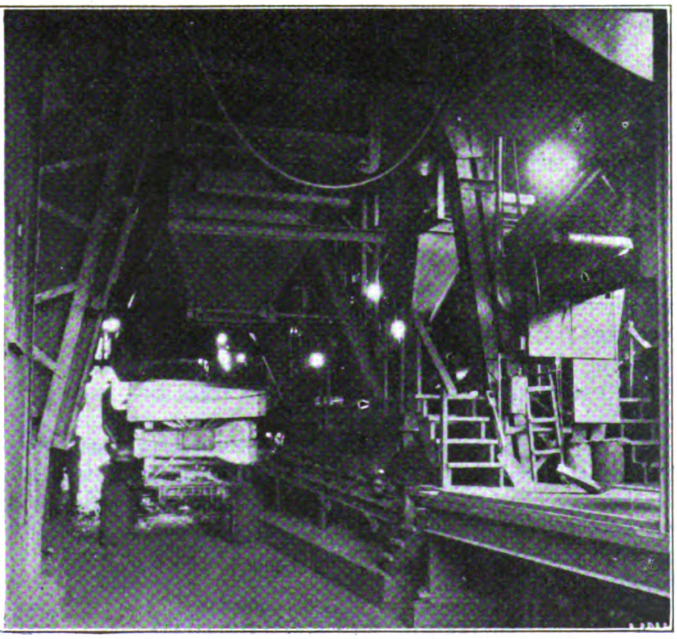

FIG 2—Weigh hoppers and method of loading trucks.

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*Engineer, Link Belt Company, Chicago.

include the use of flexible support shaking screens for separating the larger sizes, the use of vibrating screens for rescreening, and weigh hoppers to cut loading time and expense. Platform scales are eliminated. (See Fig. 2.)

The apparent advantages of the screens installed in this plant are:

1—No "blinding" of the perforations.

2—Gentle handling over the entire screen area.

3—Silent operation.

4—Less dust.

5—No destructive vibrations imparted to the supporting structure.

6—Inexpensive and quick change over to prepare various coke sizes.

A general description of the installation follows: The coke, after being quenched is dumped onto a wharf, in the usual manner, except that the floor of the wharf is a continuous 6-in. bar grating. The oversize is shipped direct as foundry coke, and the undersize passes through a two-roll crusher, which reduces the coke to 4-in. and smaller cubes. It is from this point on that the new equipment was installed. We shall describe it in units.

Belt Conveyor

A 30-in. inclined belt conveyor receives coke from the crusher and delivers to the screening plant. The drive for this conveyor is accomplished through an encased silent chain drive, from the motor and cut gears to the drive shaft; all wheels are press fitted to their shafts. The drive is located near the foot end of the conveyor, where it is out of the dust of the screen room, and accessible.

The coke received from the conveyor belt may be diverted to either one of the two twin batteries of screening equipment. A rotary disc-screen makes the first separation. Coke sizes over 1¼-in. cubes pass over the screen. Coke under 1¼ in. is received by a Hummer vibrating screen having ⅝-in. mesh cloth. The oversize coke is nut, and the pea and breeze falling through are received by a Hummer vibrating screen having ⅜-in. mesh cloth which separates the pea size from the breeze.

The cube sizes between 1¼ in. to 4 in. passing over the disc-screen are received by flexible support shaking chutes, which feed the flexible support shaking screens. These screens have 2½-in. round perforations, thus separating the egg size from the range. All sizes are received and stored in the bins underneath.

The shaking screens and chutes are actuated by ball-faced eccentrics. The drives from the motors are through silent chains remaining in oil in dust-tight castings.

The coke is fed to the disc-screen at the rate of 120 tons per hour and about 70 tons per hour are handled by the shaking screens. These require less than 10 hp. to drive. This concludes the primary sizing of the coke, except that we should add that all stationary chutes have pocket bottoms which fill with coke, thus eliminating chute wear and causing the coke to roll, rather than slide. Discharge velocity and breakage are thus minimized.

Rescreening and Loading Plant

The rescreening and loading is divided into two operations; one for shipping by rail and the other, by trucks. Provision has been made for loading both gondola and box cars and either may be loaded at the rate of 100 tons per hour.

Each of the bins is fitted with a lever operated overcut gate which controls the feed to a Hummer vibrating screen which rescreens the coke. The rescreened coke is discharged onto a belt conveyor, which feeds the loading boom when gondola cars are being loaded, or the Manierre loader when loading box cars.

The screenings are collected in hoppers beneath the screens and chuted to a belt conveyor, delivering to a bucket elevator which discharges them into the primary screening plant over the bins. The bucket elevator uses malleable buckets on a rubber covered belt.

The truck loading side is fitted with the same kind of gates and vibrating screens, but the coke is fed from the screens into individual 2000-lb. capacity weigh hoppers. The weigh hoppers are fitted with rack and pinion discharge gates operated by a hand wheel. One man weighs and loads one ton or a fraction of a ton of coke into a truck in about 50 seconds, by this method. The angle of the vibrating screen is such that when not vibrating it acts as a baffle and prevents coke from dropping in the weigh hopper. This makes it unnecessary to open and close the gate over the screen for each loading. (See Fig. 2.)

A Study of Sulphur in the Basic Process

(Continued from page 1203)

2—The effect of high temperatures in increasing the solubilities of the slags for both CaS and MnS is very marked.

3—The actual chemical composition of the slag as affecting the solubilities of CaS + MnS of less importance than the temperature of the slag.

4—The change in calcium and manganese sulphide solubilities is probably less influenced by the basicity of the slag chemically than it is by the indirect action of the more basic slag in increasing the hearth temperature.

5—The region in which solution of CaS and MnS in the slag is most rapid is the hearth of the blast furnace.

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Magnetic Control for Modern Slag Plant

In the Preparation of Slag for Utilization Efficient Design Requires Unusual Motor Controls in Regulating the Starting and Stopping of Crushing, Conveying and Screening Machinery

By W. H. McKAY*

THE France Foundry & Machine Company has recently built at Toledo, Ohio, a very up-to-date plant for crushing, screening and loading slag. There are many features of unusual interest in the design and equipment of this plant. The plant is so laid out mechanically that the conveying, crushing, screening and loading are carried out as a continuous process. The various operations through which the slag passes are so located and related to each other that the slag passes through the complete process with a minimum of travel and horsepower expenditure.

General Plan of Plant

Fig. 1 gives a schematic outline of the progress of the slag through the plant. Each machine as indicated and numbered is driven by a d.c., 230-volt motor of the indicated horsepower rating and is controlled by a magnetic starter.

The rough slag is brought from the pit by means of a 100 hp. motor-driven hoist, to the plate feeder from which it moves to the apron conveyor. As it passes over the apron conveyor, any large pieces of iron can be separated from the slag by operators stationed along the conveyor. Passing to the disc grizzly the slag is partially sorted. Those parts of the slag which are of proper size are deposited in the bins. The ungraded slag passes on to the 75-hp. crusher. The crushed slag is elevated to the top floor by means of the 75-hp. pan conveyor and passes over a magnetic belt conveyor which automatically separates all remaining portions of iron that may be in the slag.

The magnetic belt deposits the slag in the 40-hp. revolving screen and four grades of slag are separated, three of which are dropped in bins, and the fourth and largest size being returned by gravity to the crusher. The smaller sizes of slag are passed on through the 9-hp. disc grizzly, the 27½-hp. revolving screen, the 3-hp. Traylor vibrator, and finally to the 3-hp. Niagara vibrator, a certain grade of slag being separated from each succeeding machine.

There are two loading conveyors to take the sorted slag from the bins to cars, one conveyor being used for the coarse grades of slag, the other being used for fine grades of slag. The conveyor for coarse grades of slag has a 15-hp. disc grizzly to prevent any possible ungraded slag being loaded, and the conveyor for fine slag has a 3-hp. Traylor vibrator for the same purpose. The rejected slag from either of these is returned to the crusher by means of a 15-hp. dirt belt conveyor.

Electrical Control Problems

The principal control problem of this plant is to have a sequence operation such that it will be impossible for a pile-up of material to occur in case any one machine is shut down for any reason. This is accomplished by sequence interlocking of the control panels making the operation of each panel dependent upon the operation of the succeeding panels.

It is also required to be able to shut down the 9-hp. disc grizzly, machine No. 5, without disturbing any of the sequence. This machine is not always used in the process. The same thing is true of either machine No. 2 or machine No. 3 but, if both machines Nos. 2 and 3 were cut out of the sequence, a pile up would occur so that the interlocking must be such that either of these can be cut out of sequence but, in case both are cut out of sequence, the remainder of the equipment will be automatically shut down.

Machines Nos. 1 to 12 inclusive are controlled from a master control station consisting of a double-pole fused control switch and a caster "start-stop" push-button station. Each machine of this group is provided with an individual "run-safe-stop" switch. If all of the switches are in the "run" position and the master "start" push-button is pressed, the machines will start up in sequence, No. 1 being first, followed by Nos. 2, 3, etc. If, while running, an operator wishes to stop any machine, he can do so by opening its control switch. When any machine is so shut down, all machines following in the electric sequence will automatically be shut down.

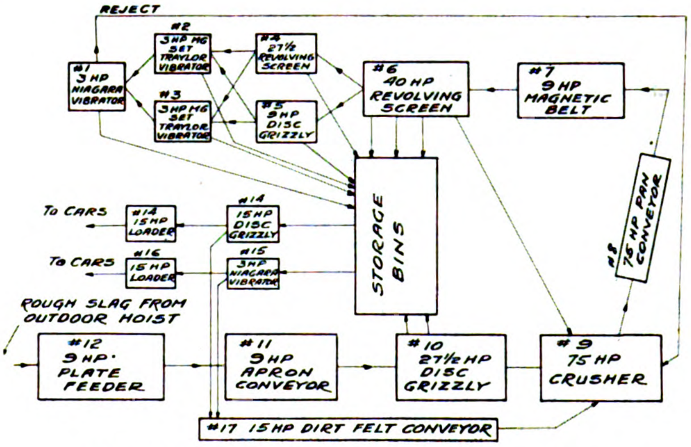

FIG. 1—Diagram showing the movement of slag through the plant.

Machine No. 5 may be shut down by means of a 4-pole, double-throw control switch without affecting the operation of the other machines. In a similar manner either machine No. 2 or machine No. 4 may be shut down without any effect upon the remainder of the machines.

Types of Control Panels

The magnetic control panels are of two general types. The panels for motors up to 15-hp. inclusive are each made up of a special arrangement of a standard unit starter whose accelerating contacts are operated by a single solenoid. The accelerating fingers of this unit starter are timed and held in sequence by means of a geared time ticker. This type of starter is very small, compact, and has a minimum of operating parts. The starting resistors are mounted directly on the back of the panel and the whole is included in a dust-proof enclosing case. These enclosing cases are wall mounted.

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*Industrial Control Engineering Department, General Electric Company.

For the motors above 15 hp. the control panels are made up of bent-frame type contactors, acceleration being controlled by geared time interlocks placed on the contactors. These panels are also of minimum size with the resistors mounted in back and enclosed in dust-proof cases mounted on the floor.

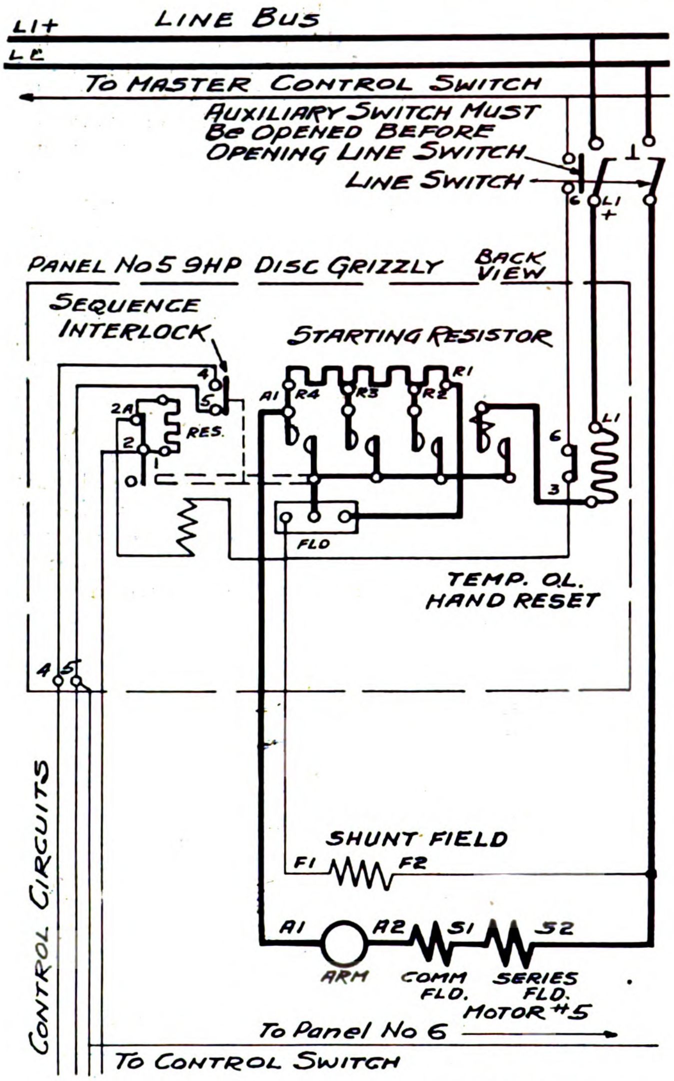

FIG. 2—Wiring for control of machine No. 5.

One very desirable feature of these panels is the economy of installation wiring. Fig. 2 shows the complete wiring for machine No. 5. The negative line goes directly from the line switch to the motor terminal, while the positive line goes through the controller, where all connections to the overload relay, the accelerating contactors and the starting resistors are a part of one controller. It is necessary, therefore, to make but three motor connections:

1—From the line switch negative to the motor negative.

2—From the line switch positive to the controller positive.

3—From the controller to the armature of the motor.

Only one shunt field connection is necessary from the motor to the controller, the other terminal being connected to the armature of the motor. Another feature of the controllers for the small motors is the use of the new thermal relay. This device is small, and has interchangeable and renewable heater elements. It has a heating characteristic approximating that of the more expensive relays used on large motors.

Automatic Stop on Crusher

The 75-hp. crusher presents some special problems in control. It sometimes happens that pieces of iron or large pieces of slag get in the crusher and cause it to jam. The overload resulting from this actuates a relay which instantaneously plug-stops the motor. When this relay functions the forward running contactors on the motor are de-energized, and at the same time the reverse running contactors are energized, thus reversing the armature of the motor. The reverse contactors are energized through a clutch relay which opens as soon as the motor has come to zero speed so that the plugging does not actually cause the motor to turn in a reverse direction, but merely brings it to a stop This same plug stopping can be obtained by means of an emergency "stop" push-button.

When the crusher motor is being started it can be jog reversed in order to clear it of slag for starting.

Electrical Safeguards

The matter of safety precautions is not overlooked. The enclosing cases make all the panels safe electrically, and all control knife switches and line knife switches are enclosed in sheet metal cases. Each panel is provided with a "run-stop-safe" control switch which may be locked in the "safe" position when it is desired to work on a machine. With the control switch locked in the "safe" position for any machine, that machine is mechanically safe, and its motor cannot be started until the control switch is changed from the "safe" position. The panels and motors are electrically safe when all the line switches are open and the master control, fused, double-pole knife switch is open.

This installation is typical of what can be done with magnetic controllers for conveyor systems. As seen in Fig. 2 the wiring scheme is relatively simple and requires in addition to the standard starters only a normally open electrical interlock for sequence control. In many cases, where the sequencing of the panel is less exacting, this can be done with the interlocks and control furnished with standard panels.

Axe Poll Steel

Axe poll or axe steel is a soft grade for the head and body of the axe, but has to be welded with the tool steel edge. It must, therefore, be good welding steel, and what is usually more severe must stand a very high heat for forming the head up square.

It is made in either Bessemer or open hearth welding steel grade with careful attention to freedom from inclusions and oxides.

Bessemer—carbon .08/10, mang. 30/50,
sulphur, under .07
Open hearth—carbon .08/12, mang. 30/60,
phos., under .04, sulphur, under .05

The POWER PLANT

Metals for Blades of Steam Turbines*

A Review of the Progress Made in the Development of Suitable Materials—Effects of Corrosion and Erosion Described and Characteristics of Various Metals Noted

By ALBERT BODMER†

PART I

IN the early days of steam turbine construction, bronze and brass were chiefly used for the manufacture of reaction vanes, and carbon steel or steel with a low percentage of nickel for the driving blades. In recent years, while continuing the use of these same metals, many others have been tried: ferro-nickels, or alloys of iron and nickel with high percentage of the latter metal, nickel brass, copper-nickel alloy, nickel-copper alloy, "inoxidizable" nickel and chromium steels, inoxidizable alloy "ATV" with high percentage of nickel, chromium, etc. It is proposed here to review these various mixtures, considering first alloys where copper plays a conspicuous part, then treating of steel containing 5 per cent of nickel, and lastly studying modern solutions which extend to chromium mixed with iron, and the combination of the improving effects of nickel and chromium.

Blading Metals of Considerable Copper Content

In a general way, brass has behaved well; its composition is about 72 per cent Cu, 28 per cent Zn, with traces of Pb; it resists very well the chemical action of steam containing impurities. Unfortunately its mechanical strength is not great, also it is only suitable for turbines of moderate power.

The characteristics of the above metal are as follows:

Tensile strength about 28 tons per square inch
Elastic limit about 22 tons per square inch
Elongation about 21 per cent

A drawback to brass is the falling away of its strength at high temperatures; at above 200 deg. C. its use is impossible.

By rolling or drawing, brass can be given any section whatever; these, moreover, are very simple for reaction turbines. This circumstance is particularly favorable for the manufacture of large sets, and explains the increased use of brass. Cold rolling to obtain a hard enough surface necessitates some precaution, since that process may render the metal brittle, especially under the influence of variations in temperature in the working of a turbine. Several builders use brass today, but only in the medium pressure stages of high power turbines, and in the medium and low pressure stages for small and medium powers.

With the increased power of modern turbines, and increased circumferential speed of blades, metals have been sought with greater mechanical strength. There are nickel brasses and nickel bronzes of various compositions. A good variety consists of 50 per cent Cu, 10 per cent Ni, and 40 per cent Zn, with characteristics as under, viz.:

Tensile strength about 33 tons per square inch
Elastic limit about 25 tons per square inch
Elongation about 34 per cent
Reduction of area about 67 per cent

The tensile strength of this alloy, as with brass, decreases rapidly when the temperature rises. By reason of its very high elastic limit, this alloy has found use for the construction of blades in the low pressure stages, where it has, moreover, given proof of its good behavior. It likewise possesses the advantage of resisting well the chemical attack of pure steam. As with ordinary brass, all sections in use in the construction of blades can be obtained by simple cold drawing, and sufficiently hard surfaces thus obtained.

The copper-nickey alloy, with about 80 per cent Cu and 15 per cent Ni, is a metal which best resists the high temperatures of steam, and can be utilized without fear of decomposition up to 350 deg. It is, nevertheless, preferably used at the medium and low pressure stages. Its mechanical characteristics are approximately the same as those for nickel bronze; it can only be used in turbines having medium peripheral speeds.

There is a nickel-copper alloy which comprises about 65 per cent Ni, 28 per cent Cu, and the remainder in various other elements. This is not an alloy obtained by mixture of nickel and copper, brought in separately; it is a very interesting product for its resistance to certain reagents, sea water for example. It is directly elaborated from a nickel ore, long considered as inferior by reason of the proportion of copper which it contains. The first tests with this metal date back about 20 years, but the difficulties of its manufacture, and its high price, have long delayed its development and use. The difficulties of manufacture seem to have been overcome during the course of recent years, but the price has remained high, having regard to the advantages brought by this metal for blade construction. The tensile strength of the rolled product varies between 38 and 42 tons per square inch, and its elastic limit is about 19 tons per square inch. These mechanical characteristics are not too greatly affected when the temperature rises, provided it does not exceed 300 deg. C. MacVetty and Mochel have intimated to the American Society for Steel Treating that Monel metal becomes weak at 500 deg., by the simple influence of temperature.* Another obstacle to the use of nickel copper in large modern turbines is its insufficient resistance to erosion. It suffers grooving more easily than would be expected from its greater tensile strength, by the shock from droplets of water contained in the moist steam, and this circumstance alienates it from the construction of turbo-motors where the circumferential speed reaches high figures. The results obtained with Monel metal are scarcely better than for brass so far as erosion in modern turbines is concerned.†

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*From World Power.

†Membre de la Société des Ingénieurs civils de France.

Nickel copper which behaves well in superheated steam, at relatively low superheating temperatures seems unadapted for blading of turbines using highly superheated steam. When exposed in an autoclave to the action of superheated steam, at a temperature of about 400 deg. C., a test piece of nickel copper becomes spoiled in a progressive way. When withdrawn, at the end of a month, and tested for bending, its surface cracks and fractures. The microstructure of samples of sound nickel copper has been compared with that of the same metal having undergone this exposure to superheated steam, showing the progress of a crack. This cracking corrosion of nickel copper by the action of superheated steam at high temperature has been approached by a phenomenon observed for the first time on ferro-nickels, namely alloys of iron and nickel with a high proportion of nickel.

At about the same time as nickel copper made its appearance, it had been thought of utilizing the relative inoxidizability of ferro-nickel. Those with 25 to 33 per cent and even 36 per cent of nickel, combined or not combined with a very slight proportion of chromium, have been used. Ferro-nickels with good behavior as regards oxidation by the air or atmospheric influences, became spoiled very rapidly in the presence of water vapor. A rod of ferro-nickel with 36 per cent of nickel, when subject to the action of saturated steam during several days, became damaged to the extent of cracking over all its surface when bent.

Five Per Cent Nickel Steels

Of metals used during recent years, steel with 5 per cent of nickel has undoubtedly served most frequently for the construction of blades, both for high pressure and low pressure stages, especially of impulse turbines. Metallurgists have established a series of steels in which the percentage of nickel varies between 5 and 8, but the preference is almost exclusively for steel with contents of about 5 per cent. These metals have shown remarkable qualities, both in superheated steam and at low pressure stages, but not with too high vacua.

The table below gives the composition and the characteristics of certain nickel steels of French manufacture which are still in current use today.

Nickel steels, and especially the type most widely used, which is steel with 5 per cent of nickel, do not become spoiled in steam within a few days, as do the ferro-nickels previously referred to. They have a durability rather better than ordinary carbon steels, but are of insufficient resistance against corrosion and erosion.

Effects of Corrosion

The temperature of steam plays an important part in the intensity of the phenomena of corrosion. There is, however, great interest in raising, as far as possible, the superheating temperature. The following is one proof amongst others:

At Gennevilliers Central Power Station two consumption trials have been made under the same working conditions and with the same loads, noting with calibrated loading apparatus, the temperatures, pressures, vacua, and power figures. The first test was made at a temperature of 380 deg. C., and the second one at 430 deg. The difference in consumption, measuring the economy realizable by the use of steam at high temperature, has been calculated at 1 per cent for each stage of 6.8 deg. C. of increase in temperature. It must be mentioned that the turbine had been constructed to operate usually at 350 deg. and exceptionally 375 deg. In the course of the experiment, the average, at the first high pressure stage, was 430 deg. The temperature several times reached 460 deg., but only during a few hours.

The moving blades had resisted satisfactorily these temperatures of 430 deg. and 460 deg. It was not the same with the fixed vanes, which, moreover, were neither calculated nor suited in their dimensions for such temperatures. The importance was thus demonstrated for constructors and users, of aiming for the highest possible superheating temperatures, and of seeking for blading metals capable of behaving well at such temperatures, not merely during an experiment of short duration, but during the whole life of the turbine. Regarding corrosion, two distinct cases have to be noted: that in which the steam arrives at the turbine loaded with salts or detrimental vapors, and that in which the water vapor arrives normally pure. Fig. 1 shows the condition of the blades in a turbine the stoppages of which were frequent and prolonged, and where the steam contained traces of chlorine. In the usual event of steam arriving normally pure, corrosion is not to be feared in turbines at work; it can only be produced during stoppage.

Unfortunately sufficient care is not taken with the installation of piping, distributing valves, and discharge valves. If the valves are not of the first quality and carefully constructed, tightness is imperfect.

Description	Treatment	Ni.	Cr.	Mn.	Va.	Tenacity, tons per sq. in.	Yield point, tons per sq. in.	Elongation, per cent
Nickel steel with 5% Ni	Annealed at 900°	5.10		0.40		36 to 43	24 to 30	25 to 20
Nickel steel with 7% Ni	Annealed at 700/750°	7.30		0.37		35 to 48	25 to 38	25 to 18
Nickel-vanadium steel, 5% Ni	Quenched and reheated to 600°	5.53	0.34	0.40	0.5	47 to 54	35 to 41	16 to 14
Nickel-chromium steel, about 5% Ni	Double annealing at 850° and 650°	4.80	1.37	0.45		about 47	about 32	16

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*"Iron and Coal Trades Review," October 29, 1926, p. 646.

†"Revue B.B.C.," December, 1924, No. 12, p. 264.

Small leakages of steam maintain a slight moisture in the inside of the turbine, and the blades, fixed and movable, become rusty. Steam always attracts particles of foreign substances, and especially where the steam passes from the superheated to the saturated state, spots are formed which the smallest leakage maintains at a certain degree of moisture. Under this layer of scale which is mixed with ferrous oxide, oxidation progresses with great rapidity. The discharge itself is often connected to a general collector, common to several machines. There likewise, by the slightest leak of the discharge valve, the phenomena just mentioned may occur. Another cause of oxidation of blades at stages where saturation commences, is the arrival of steam coming from the high pressure stuffing-box (Fig. 2). This by-pass piping, furnished with a regulator tap, ought never to be under suction, i.e. drawing air across the outer portion of the stuffing-box; on the contrary, a slight escape of steam in front of the joint-box ought to be strictly observed. From the foregoing it is clear that, by a few simple precautions, corrosion of blades may be prevented when steam is supplied to the turbine in its pure state. It is not the same in the contrary case. When the causes of corrosion which have been described are mixed up with the presence of reagents in the steam, even in extremely small quantities, the corrosion becomes so rapid that the blading is destroyed in a short time. Marine turbines and auxiliary turbines are particularly subject to this kind of occurrence. The least escape — and escapes are frequent — in the tubes and stoppers of the condensers introduces into the steam circuit salt and other chemical constituents of sea water. The effect is disastrous with blades made from 5 per cent nickel steel as with the majority of the alloy metals. Corrosion of this nature is likewise noticed, from time to time, in turbines condensed with salt water, or when that water is charged with salt impurities, as in certain mines.

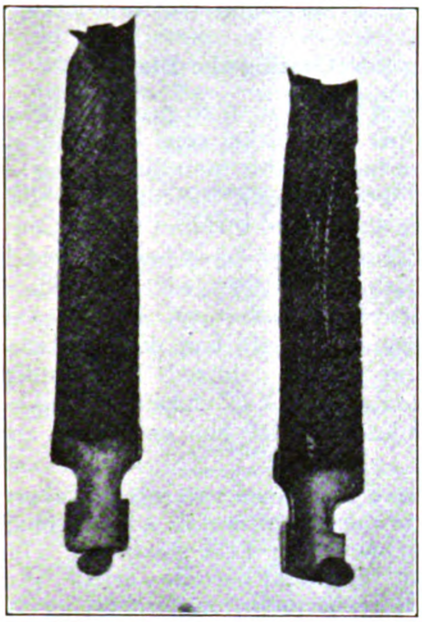

FIG. 1—Blades of five per cent nickel steel of a turbine fed with steam contaning traces of chlorine.

Erosion is much more difficult to avoid than corrosion. It occurs both on the high pressure blades and on those of the low pressure, but mostly the latter. In impulse turbines it is also frequently produced on the high pressure distributors. Owing to impurity of steam through bad jointing of tubes and stuffing-boxes of condensers, or bad purification of the feed water, the fixed and moving blades (see Figs. 3 and 4) at the high pressure stages are attacked by particles of drawn-in mud or scale. Too intensive evaporation of the boilers produces the same effects, owing to the ingress of dust and droplets of water which the superheater has not been able to evaporate. The erosion of high pressure blades can again be avoided by taking certain precautions in the management of the boilers, by some care in the maintenance of the condensers, and by active attention to the feed water.

As regards the erosion of low pressure blades, the causes have already been known for several years past; constructors, urged by the rapid progress of central stations, have sought the remedy earnestly. Erosion is due, most of all, to water contained in the steam, and if it comes in contact with a metal capable of being eroded, the effects may be such that the destruction of the blades may be complete within a comparatively short time. In modern turbines, where the circumferential speed of the blades may exceed 1,000 ft. per second, the phenomena of erosion first show themselves at the back of the extreme edge and towards the end of the blades, and these observations prove that the attack is due to the action of water contained in the steam. During the last three years it has also been ascertained that the erosion of low pressure blading increases considerably with the rise in pressure of the steam at the entrance to the turbine; this is again explained by increase in the proportion of moisture in these latter stages.

If we trace on the entropy table (Fig. 5) the lines of expansion for various pressures and temperatures at the head of the turbine, we notice, for example, that, for an effective pressure of 384 lb. per square inch, a temperature of 400 deg. C. are the characteristics of steam at the Gennevilliers Power Station, and in admitting an industrial thermodynamic efficiency of 78 to 80 per cent, the humidity of the steam for a vacuum of 96 per cent is, on emergence from the last stage of expansion, equal to about 10 per cent.

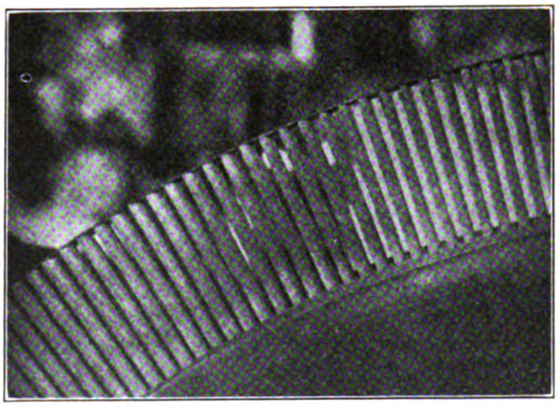

FIG. 2—Corrosion of moving blades at the stage where the steam from the high pressure stuffing-box arrives.

For steam at a pressure of 1,422 lb. per square inch and a temperature of 400 deg., retaining the same efficiency and the same vacuum, the moisture perceptibly increases, and leaving the last stage reaches about 18 per cent. On the other hand, if the temperature of the steam is increased to 500 deg. for the same pressure, same vacuum, and thermodynamic efficiency, the moisture is not more than about 12 per cent. The advantage of raising the temperature adopted at the same time as the steam pressure will thus be clearly seen. The temperature of 450 to 500 deg. surprises many engineers, but we have confidence in metallurgists to find, within a very short time, a manufacturing process for drawing tubes in appropriate steel. This will enable the construction of superheaters capable of giving the temperature mentioned above with full certainty.

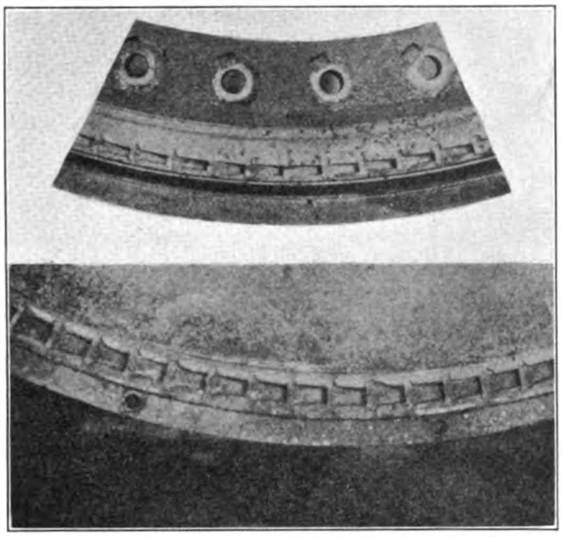

FIG. 3 (upper)—Shows the first, and FIG. 4 (lower) the second, directing ring of a turbine fed with steam containing impurities in appreciable quantities. The enlargement of the grooves caused by the mechanical action of the impurities, carried by the steam at very high speed, can be seen. The efficiency of the turbine may, in consequence of these "erosions," diminish by several per cent.

No practical and long-duration experiment has yet been made with high pressure steam, and for plants in course of working the moisture of steam, at the outlet from the last stage, consequently does not exceed 10 per cent. The majority of turbine builders consider this figure an admissable maximum. It is likewise admitted by many constructors and users that too high a humidity of the steam in the last low pressure stages unfavorably influences the output; figures are even given which would mean 1 per cent for each stage of 1.1 per cent excess moisture.

The foregoing is evidently based, almost exclusively, upon tests made with various metals, and extending over a few days or even a few hours; to the writer's knowledge no machine exists in regular service where, after a run of long duration, effects can be observed of erosion produced by steam having moisture much exceeding 10 per cent. Thus, knowing the causes of erosion, various constructors have remedied it by bringing into their own constructions the perfections necessitated. A French firm of turbine builders has for several years past placed in the low part of the low pressure guides of their turbines, water outlet passages, to allow the water to flow direct to the condenser. A Swiss company, for their turbine of 160,000 kw. under construction, has also provided water outlet passages in the fixed low pressure conduits.

The phenomena of erosion have not escaped American constructors, and to remedy it, and also to improve the thermal efficiency, they have applied a "resuperheater" by superheating the steam expanded in a high pressure turbine, before passing it into the low pressure turbine. This arrangement has not yet found application in France, and will not be further mentioned.

Coating the Blades

It has been endeavored to prolong the duration of blades of 5 per cent nickel steel by application to the surface of an inoxidizable metallic coating: chromium, tin, or zinc. For example, the blades in the last three stages of the 40,000-kw. turbines in the Central Power Station at Gennevilliers have been tinned by immersion in a bath, and afterwards polished. The result has not proved satisfactory, because after three months' working, the tin had disappeared, while the blades became rapidly oxidized. The protection of the blades by a slight layer of chromium deposited by an electro-chemical process, has not given any appreciable result.

To improve resistance to erosion, several contractors advocate the use of metals with mechanical characteristics enhanced by heat treatment. Hardening is obtained, but the metal becomes brittle. Fractures of blades are more frequent, perhaps owing to the presence of incipient cracks produced in treatment. Illustrations show a series of blades in treated steel which have broken after a very short period of working. Every user knows the misfortunes which occur as the result of fracture of blades. Consequently the use of certain treated steels for blade construction is not to be recommended.

The insufficiency of 5 per cent nickel steel for solving the whole of the problems occurring in the blading of modern turbines thus left an important gap. To bridge it, metallurgists have pressed forward the researches which they had already undertaken several years ago, making a special appeal to the preservative influence shown in a large measure to nickel, chromium, or the combination of these two elements in ferrous alloys. Success has been very unequal.

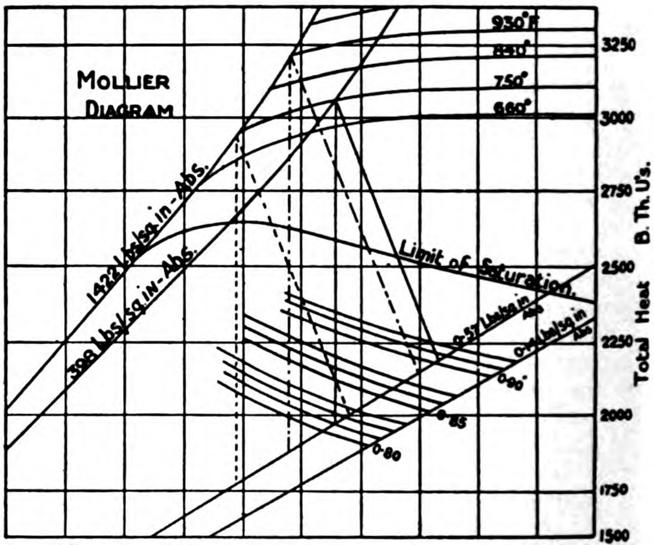

FIG. 5

The failure of ferro-nickels with 25, 33, or 36 per cent of nickel, combined or not with a low percentage of chromium, has been mentioned.

It is not proposed to discuss further the austenitic alloys with about 8 per cent of nickel and 18 per cent of chromium, represented by various marks. Their excellent qualities of resistance to various acids and sea water had, in Germany, foreshadowed their use in turbines, but only for the fixed blades. According to reports this hope has been disappointed. These metals are very difficult to machine, and their treatment is of the most delicate kind.

Steel with High Proportion of Cromium and Small Nickel Content

Germany has recently put upon the market a steel containing 0.5 to 1.2 per cent nickel and 8 to 10 or perhaps even 15 per cent chromium. The following are its characteristics at ordinary temperature and at 400 deg. C.:

	Ordinary temperature	400° C.
Tensile strength about	45 tons per sq. in.	38 tons per sq. in.
Elastic limit about	35 tons per sq. in.	30 tons per sq. in.
Elongation about	27 per cent	18 per cent

This metal, sometimes called inoxidizable, is only so in a relative manner. Its use has been tried in modern turbines, especially in Germany. It is not quite exempt from corrosion, and as regards erosion the practical results of long duration show it is again wanting.

Steels with 13 per cent chromium were introduced in England. They are now manufactured in all countries producing special steels, under an already considerable number of brands, comprising, naturally, articles of unequal value, according to the claims of the producing steel-works; they are commonly called "stainless" or "rustless," i.e., unstainable or non-rusting.

The hard grade is called stainless steel, and the soft grade stainless iron. Resistance to oxidation, in the first, is associated with two conditions: correct treatment of the metal by hardening and tempering and perfect polishing of surfaces. Its trial for the blading of turbines has given dissatisfaction.

For the soft grade, precise heat treatment is not so indispensable, if comparative inoxidizability can be considered satisfactory. But the obtaining and retaining of as perfect a polish as possible is necessary. This grade is therefore more suitable than the first-mentioned for the manufacture of movable blades. On the other hand, the difficulty remains as great for the construction of the fixed blading: steels with 13 per cent of chromium are really steels, i.e., alloys which harden by quenching, and which become transformed and changed in their nature under the influence of thermal variations: the arrival of hot cast iron at the end of a steel blade, with 13 per cent of chromium, produces heat treatment which is undesirable and of uncontrolled intensity, and which puts the steel into an unknown and indeterminate condition. The relative inoxidizability of steel with 13 per cent of chromium is connected with the state of polish of its surface. Hence it results that, if erosion happens to attack and remove the polish, the resistance to corrosion must relax. It has been sought to increase the resistance to erosion by hardening the blades, after their complete machining and finishing, by heat treatment. This is a serious operation, extremely delicate to arrange so as to give successful results.

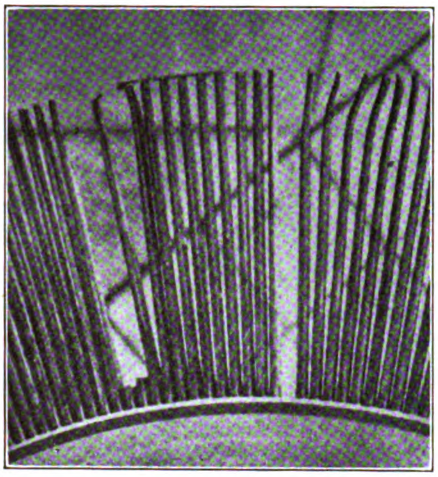

FIG. 6—Blades of treated five per cent nickel steel broken after 1,200 hours of operation.

The mechanical characteristics of 13 per cent chromium steel, of mild grade, are as follows:

	In the condition after hot rolling, cooled in air	Softened by annealing at 800°, cooled in ashes
Tensile strength	45 to 50 tons per sq. in.	35 to 40 tons per sq. in.
Elastic limit	32 to 38 tons per sq. in.	26 to 38 tons per sq. in.
Elongation	20 to 15 per cent	22 to 18 per cent

(To be continued)

Generating Units of Exceptional Size

The New York Edison Company has just closed a contract for the installation in its new East River generating station, located on East River at Fourteenth Street, of steam generating units that will supply the steam to drive the largest single-shaft, single-unit electric generator in the world. This turbo-generator, which is still in process of manufacture, will develop 160,000 kw., or 215,000 hp. So huge is this giant machine that it will be delivered in separate parts by its builders, the General Electric Company. The delivery and setting up of the first part of this generator is expected to take place next October or November.

The steam generating units, which will be of the new water wall type, are to be installed by the Combustion Engineering Corporation, which reports that this contract is one of the largest in its history, and that the requirements of the contract will make these steam generating units the largest in the world. The contract calls for the installation of four complete steam generating units.

These units will have an aggregate heating surface of 45,120 sq. ft. each, and the contract contains a guarantee that each of the four will produce 550,000 lbs. of steam per hour. Engineering studies are being continued, New York Edison Company officials said, looking to obtaining a maximum capacity each of 800,000 lbs. or more per hour.

Furnace Volume and Combustion*

High Temperatures for Combustion Must be Maintained, Requiring Proper Design of Combustion Chambers—Refractory of Suitable Quality a Problem

By HARRY JACOBS

THE basis of steam generation can be divided into three main factors: First, crude or original source of heat, such as oil or coal, etc., second, the conversion into heat or Btu.; and third, the transposing of the Btu. into a medium that can be controlled, such as steam.

The first or crude form of the Btu. may be considered as coal, which may be divided into two clearly defined types, the first being practically pure carbon, commonly known as anthracite, the chief characteristic of which is a very short flame, and the greater portion of the heat of which is radiant heat. The second type covers a very great variation of qualities, all of which are embraced under the one heading "bituminous." It is this large range and the inability to produce exactly the same type of coal that make the consideration of combustion a very difficult problem; in fact, combustion with all its various phases bears a greater responsibility for poor boiler efficiency than all the rest of the equipment employed in the generation of steam. It is therefore this factor which should receive greater attention and study.

Conversion of Steam

The third factor referred to is the conversion of the Btu. into a controllable form such as steam. This conversion or transposition is taken care of in the boiler. The type of this equipment does not seem so important as the final harnessing of the Btu., although it receives a great deal of the attention as to the merits of one type or another of boiler. One thing that is fairly well established is the actual transmission of heat from the furnace to the boilers—that is, just how many heat units can be crowded through a given area of boiler surface in a given time.

The Btu., in reality, is the main consideration. In all of its many forms science has ascertained the exact number of these Btu. that are contained in a given quantity of a combustible, and it is the difference between what nature has provided in the crude form and what can be harnessed or controlled that is called efficiency. It is during the second and transition period where so many valuable heat units are lost, when they could be saved with proper consideration and design.

This second stage of conversion takes place completely in the combustion chamber, so that when the Btu. has been liberated from the coal, if the combustion is not completed, carbon will remain in its original state and pass off as smoke. As the importance of completing this combustion is paramount, sufficient time should be given to bring every particle of the air and gases to a sufficiently high temperature that they will unite and explode. As the fixed carbons complete their combustion practically within themselves the matter of combustion chamber volume has its being almost entirely with the volatile combustibles rather than with anthracite coals.

In connection with the handling of these combustibles the point that has to be borne in mind is that to complete the combustion a temperature in the neighborhood of 1100 deg. F. or greater has to be reached, or the passing of unconsumed combustible gases with their corresponding heat loss will result. The accompanying table shows the comparative ignition temperatures of a number of important combustible substances possible from coal. Due to the wide controversy over the ignition temperatures of several of these substances, they are not claimed to be accurate, but merely included to show the region in which such temperatures lie.

Ignition Temperatures.

Combustible	Symbol	Ignition temp. of
Sulphur	S_2	470
Fixed carbon bituminous coal		766
Fixed semi-bituminous coal		870
Fixed carbon anthracite coal		925
Acetylene	C_2H_2	900
Ethane	C_2H_6	1000
Ethylene	C_2H_4	1022
Hydrogen	H_2	1130
Methane	CH_4	1202
Carbon-monoxide	CO	1210

Being an average of the different ignition temperatures of coal based on their qualities, this temperature may vary slightly, but as this is the critical point, the temperature as a whole should be considerably higher to ensure that all gases will at least be at the critical point. Just to emphasize the difference in temperature between the shell of the boiler and the furnace gases it should be remembered that from a pressure of 1 lb. to a pressure of 400 lb. per sq. in., which covers pressures most commonly in use, the temperatures vary from approximately 212 to 448 deg. F.

Factors Reducing Temperature

As previously pointed out, for all practical purposes the temperatures of gases and air should be maintained at 1100 deg. F. or more. They would not need contact with a surface at 448 deg. F. or less for any length of time before they would be chilled below the temperature necessary to complete combustion, and, therefore, become an absolute loss. In this connection there are two other methods whereby the temperature can be reduced below this critical point, and both these are too important to be overlooked, especially as they are both controllable. The first of these is the air supply for combustion, and one that is usually most neglected.

The second, however, the infiltration of air through the settings, is one that can best be taken care of when the settings are being built. The present combustion-chamber volume is much greater than was used in the early days where the boiler was practically set on the fire bed, limiting the furnace volume to a

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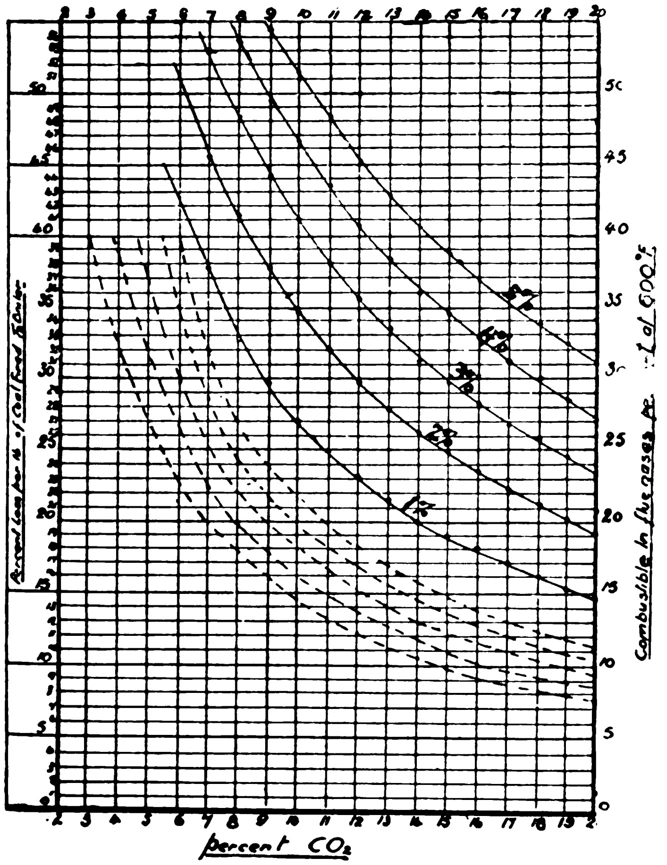
From Mechanical World and Engineerng Record.

few cubic inches to the pound of coal burned. In some extremely modern settings 8 cu. ft. of combustion-chamber volume have been allowed per horsepower developed, the only arguments against the large size combustion chamber being the cost of the brickwork and the cost of maintenance in relation to the added efficiency obtained, this relation being the deciding factor in the majority of cases.



Relation of Furnace Volume to Combustion Efficiency.

In this chart it is assumed that there is no combustible in the flue gases, and that the tubes are clear and free from scale.

In general, however, two factors go to make the cost of "volume" prohibitive, the first of these being of minor importance—namely, the thickness of a common brick wall; and the other is the firebrick. Firebrick has been in common use for so long that it is practically taken for granted at present, and as even the poorest firebrick has practically the same fusing temperature as a high-grade firebrick, purchasers of this product have very often been lulled into a false feeling of economy by buying firebrick with too much regard to the fusing point alone, instead of considering the quality and methods of manufacture.

It is difficult to take a brick of one analysis and consistency and expect to be able to use it on a pulverized fuel or stoker job or in an oil-burning furnace and get the same results. This point seems to be evident enough, because in the case of the pulverized fuel or stoker job the brick is wanted for the purpose of reflecting the heat so as to bring up or maintain the temperature of all the products of combustion until they have completed their combustion.

The brick has to be of a consistency that the oily substance will not impregnate it. This latter condition also applies to metal crucibles, except that, instead of contending with an oily substance, it is the impregnation of the metals. Therefore, proving that the analysis is right in order to give the brick the proper characteristics is necessary to give the right consistency to withstand the different character of the work. The looser the structure of the brick the greater is its resistance to heat transmission, and therefore the freer the structure the better it should be as a reflector. Bearing this in mind, the next thing to consider is the fusing point of firebrick as a cone test.

Fusing Point of Firebrick

What few people stop to consider is that as weight is imposed on firebrick its fusing point drops, from which it becomes obvious that in designing a combustion chamber some method must be employed that will not impose excessive weight on the lower brick. If this is done the next consideration is the allowance of sufficient expansion space so that the brick will not create a self-imposed pressure. Here again rises the question of ingredients possessing a very low coefficient of expansion. Therefore this expansion space can be minimized, reducing the possibility of air infiltration. Since this article is not one on firebrick, no discussion will be made of the combustion chamber, except in so far as the type of brick has its effect on the point being considered.

Combustion of Furnace Gases

The question of radiant heat brings in the importance of the speed of the furnace gases, and it may be pointed out that a speed of 150 to 200 ft. per min. is not by any means a high velocity. With this in mind, it need only be realized that in connection with a return tube boiler, providing the bridge wall does not throw the unconsumed product of combustion against the shell of the boiler, and the combustion space at the rear of the bridge wall is large enough, the consumable gases have only 6 to 10 seconds before they have to pass through the tubes of the boiler.

Consideration of the chart will show that 1 per cent of burnable gases in the flue gases actually lose more heat than corresponds to a gain of 3 to 4 per cent in the CO_2.

The combustible in the flue gas is of such great importance that any restriction of the combustion-chamber volume is tantamount to a restriction of the combustion—that is, unless ways and means are devised for supplying everything to the combustion chamber at the proper temperature, so that there will be no delay in the completion of the combustion.

This combustion at present time looks to be as near perfection as seems possible, and it would need practically a completely new kind of material for the combustion end before it could be improved upon. The point which it is intended to bring out is the fallacy of trying to develop more boiler horse-power by the use of mechanical methods, and at the same time increase the efficiency without enlarging the combustion-chamber space.

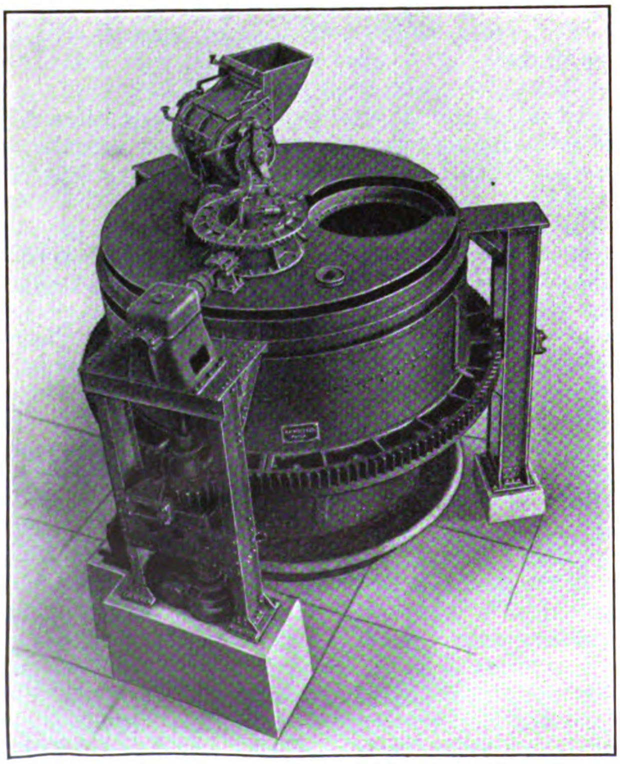
It requires very little figuring to find that the more gases generated in a given space the greater the velocity, and therefore the less time elapses for the completion of combustion. The question may be asked, "What velocities is it possible to obtain under normal draught conditions?" The answer may be given that velocities up to 60 ft. per min. are not considered high in chimney practice. Therefore this same velocity might be possible through the setting, although perhaps not advisable.

WITH THE EQUIPMENT MANUFACTURERS

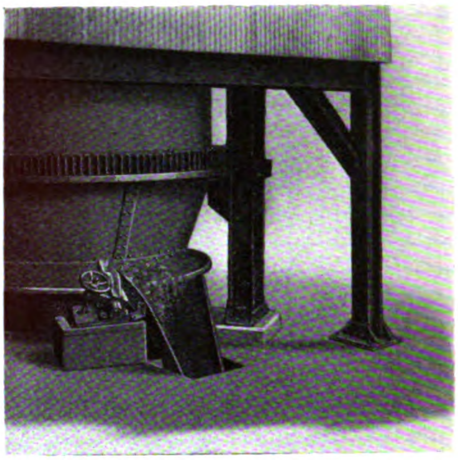
Full Mechanical Gas Producer

R. D. Wood & Company, Philadelphia, Pa., has recently brought out a new full mechanical gas producer known as type SB-10. It operates on the same principle as the company's "Heavy Duty" gas producer and the manufacturer claims the new producer has increased gas making capacity and lower power, steam and water consumption.

The producer has many features that render it efficient including full mechanical operation from the feeding of coal to removal of ashes. Positive agitation of fuel bed is attained by means of a single, straight poker bar, which can be easily and quickly replaced. The mechanical coal feeder operates without metal to metal contact between stationary housing and multiple pocket drum. This construction greatly reduces wear, and gas leakage between the stationary and moving member is prevented by means of a water seal. The revolving ash pan, supported by three accessible conical rollers rotates at the same speed as the producer shell. This construction prevents the grinding of ashes and subsequent increased resistance to the passage of the blast. An adjustable ash plow permits continuous plowing of ashes, regardless of the amount of coal gasified. The ashes are further agitated and moved from the center of the producer towards the outside of the ash pan by means of a stationary agitating blade. A noiseless turbo-fan blower of multiple steam nozzle design insures greatest economy in steam consumption and perfect control of blast saturation.



A self-supporting construction permits installation independent of producer building. The three supporting columns carry the conical shell supporting rollers and horizontal thrust rollers. The water cooled top plate is of steel plate construction, heavily reinforced by structural steel shapes and provided with checkered cover plates.



Mechanical ash discharge.

A simple driving mechanism is provided for the continuous rotating motion of the producer shell and agitating bar, each being driven by a single shaft without the employment of levers, links, universal joints, etc. The layout of producer foundation is simple, requiring about 15 cu. yd. of concrete.

From an installation in a steel mill the following operating data have been obtained. The coal gasified is Lincoln Gas Coal Company's egg and nut "Pittsburgh Vein" of the following analysis:

	Per cent
Moisture	1.38
Volatile matter	38.40
Fixed carbon	55.90
Sulphur	2.16
Ash	5.70
Btu. per lb.	13,580
Fusing point of ash, deg. F.	2,200

The rate of gasification, depending upon the demand of the heating furnaces, varied from 3,750 lb. to 5,700 lb. per hour, or from 47.8 lb. to 72.6 lb. of coal per sq. ft. of fuel bed area. The gas produced from this coal was of uniform quality and averaged 162.3 Btu. (low value at 62 deg. F.) per cu. ft. containing 46.5 per cent combustibles.

Average Gas Analysis.

	Per cent
CO_2	5.8
CO	26.2
CH_4	3.8
C_2H_4	.8
H_2	15.7
O_2	.2
N	47.5

The analysis of the producer ash given below shows how thoroughly the coal is converted into gas, the carbon content being only 0.355 per cent of the total carbon contained in the coal as charged into the producer.

Average Gas Analysis.

	Per cent
Silica	43.10
Alumnum oxide	25.95
Ferric oxide	23.35
Sulphur	.44
Phosphorus	.06
Lime	1.50
Carbon	5.60

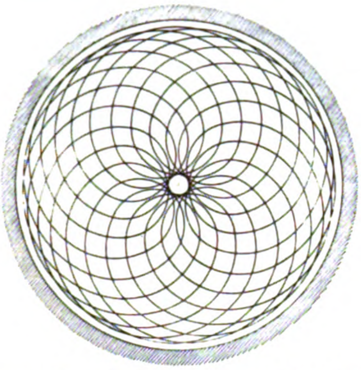


Diagram showing agitation of the fuel bed during six revolutions.

During the several months of operation covered by the period of observation, no hand poking was done and the fuel bed at all times was level and loose, permitting a ½ in. diameter measuring rod to be pushed down its entire length. A gas temperature of 1400 deg. F. was maintained, no hot spots nor blow holes were developed and the wall remained free of clinker. Ashes were plowed continuously. The turbofan blower operated at approximately 50 lb. steam pressure and the total power consumption under maximum load was less than 3 hp. The agitating bar used 270 gals. of cooling water per hour, the overflow cooling the plate.

An Instrument for Measuring Fuel Wasted Up the Chimney

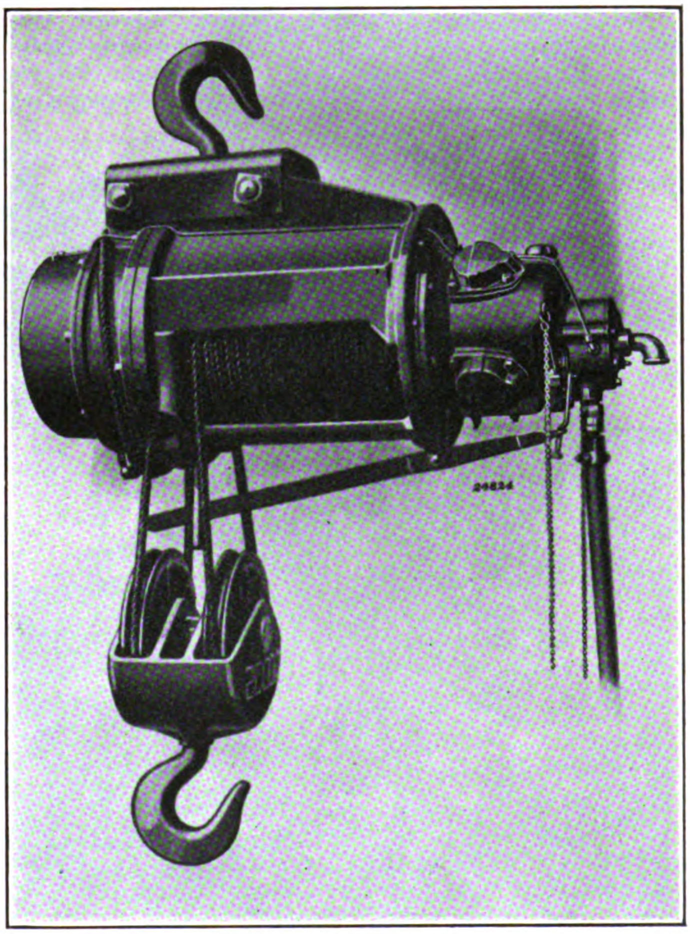
In the average boiler plant, 35 per cent or more of the heat in the fuel burned under the boilers is lost with the stack gases. This can be prevented with Apex CO_2 Recorders which are today being used by the majority of fuel consumers throughout this country and abroad.

There is only one best adjustment for the carburetor of your automobile. Too much air—or too little—wastes gasoline. So it is with your steam boilers. If your fireman does not proportion the air supply just right at all times, you will surely waste a lot of fuel. The electrically operated Apex CO_2 recorder and indicator manufactured by the Uehling Instrument Company, Paterson, N. J., tells the fireman how to obtain correct air supply continuously, irrespective of changing load conditions of the boiler. They take the guesswork out of firing, thus enabling the fireman to produce more steam with less fuel, while at the same time lightening his labor.

One of the most serious and persistent of fuel wastes is caused by burnt-out spots in the fuel bed. These are detected quickly by the Apex instruments, enabling the fireman to cover them up and stop the waste. Likewise, it is practically impossible to maintain the correct thickness of fuel bed or the proper damper adjustments for the rate of driving, without the guidance of a CO_2 instrument. Air infiltration through cracks in the setting and through cracked or warped doors or other openings often chills a boiler to such an extent that the fuel bill is out of all proportion to the steam produced. Such adverse conditions are easily prevented because they are shown up in a very positive way by a marked reduction in the percentage of CO_2 recorded. Incorrect methods of firing and of cleaning fires gives way to efficient methods when the fireman is provided with these simple guides.

New Air Motor Hoist of 10-Ton Capacity

A new air motor hoist of 20,000 lbs. capacity is now being furnished by the Ingersoll-Rand Company, 11 Broadway, New York City. In railroad shops this hoist is used for handling locomotive drivers at lathes and presses, and for other heavy lifting work which would ordinarily tie up a crane.



The hoist construction employs a powerful four-cylinder air motor geared to a rope drum and all enclosed in a compact and dirt proof housing. The gears are made of special steel and heat treated to insure extra strength and wearing qualities. They operate in a bath of semi-fluid grease, completely enclosed. Ball bearings or bronze bushings are provided at all points where experience has indicated that they will add to the efficiency and life of the hoist.

An automatic brake, of similar design to that used in other Ingersoll-Rand Air Hoists, is incorporated in this new size. This safety brake automatically holds the load at any desired position for any length of time, regardless of air pressure.

Instant and complete control of the hoist movement is obtained by a graduated throttle and a well balanced motor. The latter is practically without vibration. The cylinders are renewable and interchangeable making it easy and inexpensive to renew the cylinders if worn after long service.

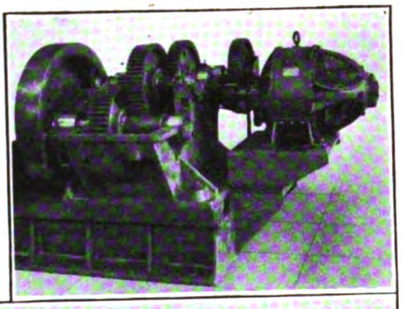
The hoist is designated as size "G" and has a maximum lift of 16 ft., cable 9/16 in. diameter x 83 ft. length, pipe connections ¾ in., weight equipped with top hook 1300 lbs., weight equipped with chain driven trolley 1800 lbs.

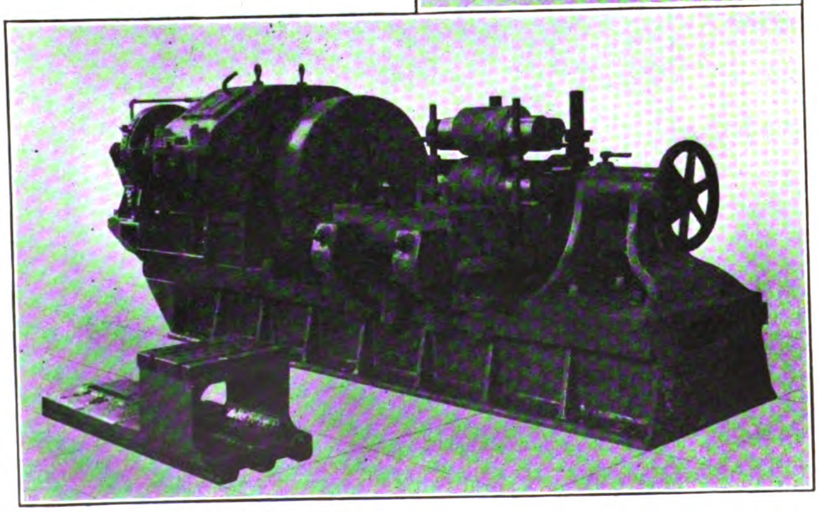
The hoist can be furnished with either a top hook or a chain driven trolley as standard. The company is prepared, if necessary to build special trolleys to meet customer's requirements.

Roller Bearing Equipped Roll Lathes

Mackintosh-Hemphill Company, Pittsburgh, Pa., manufacturers of rolling mills and rolling mill equipment, recently completed two direct motor driven, heavy duty roll lathes. Both lathes are equipped with roller bearings on all gear shafts, which is a recent departure in roll lathe design.

This improvement fills a long felt need for an absolutely "fool proof" drive, operating with a minimum amount of friction and requiring a minimum amount of attention from the operator.

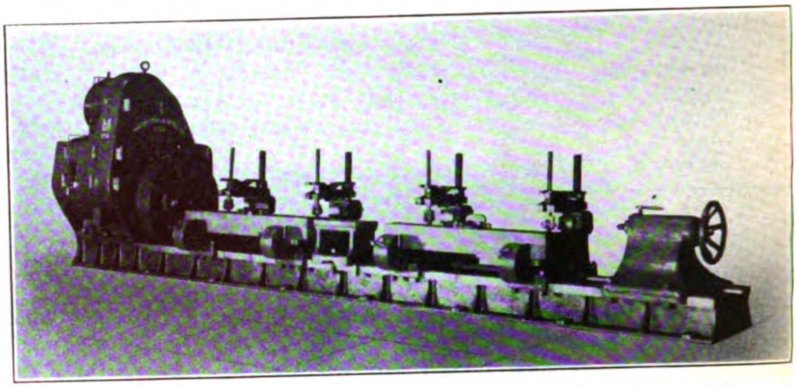




This use of roller bearings on the gear shafts insures absolute alignment of gears at all times, eliminating chatter and wear. Freedom from wear and improved lubrication of the moving parts, require that the cover be moved only for an occasional examination.

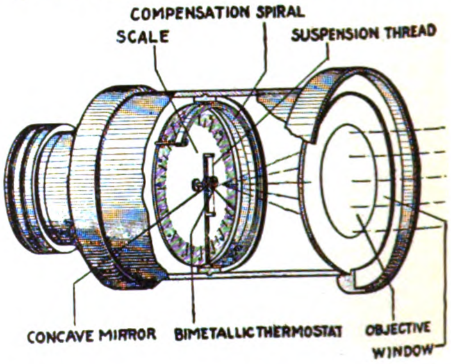
The lathe shown in the previous illustration is designed to operate at speeds ranging from .73 to 6.5 rpm. It is equipped with totally enclosed head stock, which permits the gears to dip in a bath of oil in addition to spray lubrication, which is provided.

The other lathe illustrated below embodies all the features of an up-to-date machine of this type. The head stock is equipped with roller bearings and provided with oil spray lubrication for the gear teeth and pressure grease lubrication for the bearings. The motor is mounted directly on the head stock and is connected to the head stock drive through a flexible coupling. The lathe is capable of turning simultaneously two rolls, each 8 ft. 6 in. long, 36 in. maximum diameter.



New Pocket Radiation Pyrometer

The Colonial Supply Company, of Pittsburgh, Pa., is featuring a portable instrument for measuring high temperatures known as the K & S pocket radiation pyrometer. This instrument, as illustrated, comprises a 1⅛ in. diameter collecting lens of 2 in. focal length, a small bimetallic spiral suitably hung at the focal point actuating a pointer which later moves over a direct reading temperature scale. Automatic compensation for room temperature variation is provided and the scale is viewed through an ocular. A color screen protects the eye when reading very high temperatures. The instrument is well enclosed in its mounting which measures 6 in. long, 2 in. diameter and complete weighs 6 oz.



The temperatures are read direct, no comparisons or calculations being required. It is made in several scale ranges.

TRADE PUBLICATIONS

The Bristol Company, of Waterbury, Conn., has compiled a quite complete list of the applications and instrument recommendations for the iron and steel industry in a bulletin of 27 pages. Bristol instruments that are used in these industries are also described in this bulletin.

* * *

Three pamphlets dealing with improvements in blast furnace equipment have been issued by James P. Dovel, engineer and contractor, American Traders Building, Birmingham, Ala. Information is given in these pamphlets concerning the Dovel inwall cooling system, the Dovel metal top, the Dovel gas cleaner, washer and settling basin, etc.

* * *

Caterpillar power for mines, and quarries, factories, public utilities, and railroads is set forth in four attractively arranged pamphlets published by the Caterpillar Tractor Company, of San Leandro, Calif. The pamphlets are well illustrated by views which show the machines in service. Transportation of materials over muddy roads through deep snow and across rough tracts of country is made possible in many instances by the use of tractors.

* * *

"The Foreman and Labor Turnover," a booklet edited by the Metropolitan Life Insurance Company, has for its purpose "to show how foremen can aid in the control of labor turnover and how their interest in such a program can be maintained." Forty-two manufacturing companies co-operated in furnishing data for this study.

* * *

Two bulletins, "Arc Welding in Industry" and "Arc Welding in G-E Factories," issued by General Electric Company, describes the many uses to which this form of welding is applicable and the savings involved in particular instances. Both bulletins are well illustrated.

* * *

The Superheater Company, 17 East 42nd Street, New York City, has published a concise, well arranged booklet containing steam tables. Entropy curves are included.

* * *

"Nema Handbook of Apparatus Standards," seventeenth edition, 1928, 348 pages. Published by the National Electrical Manufacturers Association, 420 Lexington Avenue, New York City. Test, performance and manufacturing standards of electrical apparatus have just been published as the Nema Handbook of Apparatus Standards, formerly known as the Electric Power Club Handbook of Aparatus Standards. The book embraces standards of electric power, control and measuring apparatus for the generation, distribution and utilization of electric energy. Each section of the handbook, covering such apparatus as motors and generators, industrial control, transformers, switchgear, measuring instruments, electric welding, etc., is complete in itself, all the rules relating to each product being grouped together. Standard definitions, abbreviations and symbols are also included for each class of apparatus.

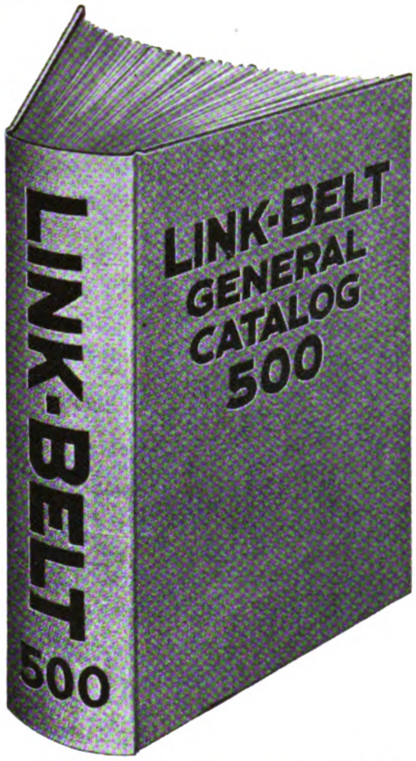
Bulletin No. 12-A, from the American Gas Furnace Company, Elizabeth, N. J., contains considerable information pertaining to the principles which control the process of carburizing. It also contains a description of the various types of furnaces manufactured by this company for carburizing articles of different forms, such as ball races, axles, shafts, etc. The furnaces (or machines) are of the rotary and vertical types. The bulletin is well illustrated.

* * *

The Celite Products Company in their new illustrated bulletin No. 338 features better concrete made by the addition of celite giving many examples and showing tests and formulae for mixing.

Link-Belt Company Issues 1,088-Page Catalog and Engineering Data Book

If the amount of usable information put into a general catalog is any criterion of its worth then the Link-Belt general catalog 500, published by Link-Belt Company of Chicago, Indianapolis and Philadelphia, is a good example of what an informative general catalog should be.



It consists of 1,088 pages and not only covers in engineering data and list prices, the complete chain, sprocket, power transmission, elevating and conveying and engineering divisions of that company's business, but contains considerable other data for which the engineer has use.

In developing this book, it was evidently their purpose not only to make its contents of engineering information so ample that engineers might design plants of a standard character without their aid, but also to supply price lists so complete as to enable the experienced buyer to determine net prices of his purchases.

The book is admirably arranged to serve these purposes. In addition to being an unusual engineering catalog, it is a text book of the conveying, elevating and chain transmission art.

TRADE NOTES

The Gas Cleaning Engineering Corporation, 320 Broadway, New York, has been organized to design, engineer and contract for the construction of improved dry gas cleaning apparatus, and will be pleased to mail upon request a recently published bulletin on "Blast Furnace Dry Gas Cleaning."

* * *

The Illinois Central Railroad Company has purchased one 600-hp. oil-electric locomotive from the Ingersoll-Rand Company and the General Electric Company. It will be used in switching service in the city of Chicago.

* * *

Four new Linde plants have recently started production of oxygen and are now serving the local demand in their respective localities. On July 3, a plant at 631 South Seventeenth Street, Harrisburg, Pa., started operating in charge of J. J. Naber. A plant at Seventeenth and West Lawrence Streets, Allentown, Pa., in charge of W. Barber, began production on July 18. On August 1, the Shreveport, La., plant, located at Foster and Thomas Streets, in charge of F. T. Rueger, started operating. Last of all, a plant at First Avenue and B Street, South Charleston, W. Va., was added to the chain. Ed Pohlman is superintendent at the latter plant, which started manufacturing August 10. The opening of these plants brings the total up to 52 Linde oxygen producing plants throughout the country.

* * *

Recent contracts awarded the Costello Engineering Company, Pittsburgh, include two of its patented continuous pair furnaces equipped with metallic recuperators for the Inland Steel Company, Indiana Harbor, Ind., one car-type annealing furnace equipped with full automatic control for the Monroe Steel Castings Company, Monroe, Mich; and all the furnaces for the new addition to the Park works of the Pittsburgh Crucible Steel Company, Pittsburgh, comprising sheet furnaces, pair furnaces, and double-chamber box annealers.

* * *

The city of Milwaukee is preparing to build a complete testing laboratory estimated to cost $60,000. Preliminary sketches have been completed by E. C. Malig city architect, and the preparation of detailed plans awaits the final selection of a site from a number under consideration. The building will be two-story, about 40 x 100 ft. Manuel C. Cutler is supervising engineer of the department of bridges and public buildings. Roland E. Stoelting is commissioner of public works.

* * *

The Leinert Valve Company, of Chicago, has received an order from Germany to equip several blowing engines with Leinert patented automatic plate valves. This company has also received from a European steel works an order for 2,000 meters of wire rope.

* * *

James T. Castle reports the following purchasers of Union Water Tube Boilers. Pittsburgh Coal Company, one 300 hp.; Borough of Etna, Pa., one 258 hp.; Canfield Oil Company, Coraopolis plant, three 350 hp.

The Stanley P. Rockwell Company, of 66 Trumbull Street, Hartford, Conn., announces that they have severed business relations with the Ryan, Scully & Company, of Philadelphia, Pa., whom they have represented in the New England territory for several years past in the sale of their heat-treating equipment. However, they state that they will continue to guard the interest of customers in the servicing of their Ryan equipment, which have been purchased through them.

Very stortly they expect to announce a new connection with a firm of national reputation, which will enable them to so round out their line that they will be in a position to offer all types of heat-treating furnaces and control from the smallest bench furnace to the largest automatic equipment for continuously heat-treating large production with either fuel firing or electric heating. In the meantime they have already made arrangements to take care of pending negotiations or other equipment for immediate needs.

* * *

Mr. Charles J. Arthur has been added to the Philadelphia office of the Wagner Electric Corporation, of St. Louis, as a salesman. Mr. Arthur was until recently sales engineer for the A. R. Amos, Jr. Company of Philadelphia.

* * *

The American Heat Economy Bureau, Inc., has recently received an order from the Carnegie Steel Company to equip one of the heating furnaces at their Duquesne Works with automatic control equipment for regulating the combustion of fuel in the furnace. The desirability of such control has been well shown by a recent installation on a slab heating furnace, where the heated slabs discharged from the furnace have a very thin uniform scale which readily breaks off at the rolls; while the flame in the furnace is simply a haze at the rear end.

Purpose Standardization of Mechanical Equipment

The initiation of four new standardization projects for mechanical equipment under the auspices of the American Engineering Standards Committee has been requested by the American Society of Mechanical Engineers. These projects, which are now being considered by the A.E.S.C., are:

Standardization of stock sizes, shapes and lengths for iron and steel bars including flats, squares, rounds and other shapes. The standardization of Woodruff Keys, a project now under way under A.E.S.C. auspices, has emphasized the necessity of standarizing the sizes and shapes of iron and steel bars, particularly in reference to the dimensions and tolerances of hot and cold finished bars.

Standardization of splined shafts and splines. It is recommended that the scope of this subject include a study of the relations between keys and shafting of various kinds; square and flat keys, both parallel and taper; splines and double keys, etc. Both solid and hollow shafting will be considered.

Standardization of rolled threads for screw shells of electric sockets and lamp bases. The purpose of this project is the development of thread standards for the new "intermediate" size lamp socket and base and the review and revision of present manufacturing practice for the older types.

Standardization of dimensions of stud bolts, including thread dimensions and working tolerances.

NEWS OF THE PLANTS

The Republic Iron & Steel Company, of Youngstown, Ohio, acquired control of the Steel & Tubes, Inc., of Cleveland, Ohio. Myron A. Wick will continue to manage Steel & Tubes, Inc., and will become a member of the executive committee of Republic. The merger will afford a greater opportunity for the use of the coal and ore resources of the Republic Iron & Steel Company.

* * *

Tennessee Coal, Iron & Railroad Company has completed a second big blast furnace at Fairfield with a capacity of 600 tons of iron daily. The new Hamilton shaft coal mine, which will have a daily output of 4,000 tons, is also completed.

* * *

Plans are under way to combine the Lebanon Iron Company and the Scranton Bolt & Nut Company, forming a new concern to be known as the Wrought Iron Company of America. It is expected that Charles Hart, now president of the Scranton Bolt & Nut Company and president of the Delaware River Steel Company, of Chester, Pa., will be made president of the new company.

* * *

The Columbia Steel Corporation, of San Francisco, with plants at Provo, Utah; Portland, Ore.; and Pittsburg and Torrence, Calif., will make extensions including a tin-plate mill at Pittsburg, Calif., of 50,000 tons annual capacity. The mill will start operations early in the next year.

* * *

The two blast furnaces and stoves of the Temple Furnace Company, Temple, Pa., have been sold to Aaron Aronsky, Pottstown, Pa., the highest bidder on the equipment, who will scrap the furnaces and stoves. Philip Brenner & Company, Reading, purchased the blowing engines. Other portions of the equipment went to other bidders. The sale was conducted by Samuel T. Freeman & Company, Philadelphia, by authority of Paul Brooks, receiver for the Temple Furnace Company.

* * *

After nearly nine years continuous operation producing in that period 1,835,000 tons of pig iron, the "A" stack of the Toledo Furnace Company, of Toledo, Ohio, operated by Pickands, Mather & Company, Cleveland, has been blown out. The furnace blown in November 6, 1919 has not been cold since that date, the daily output for the past year being about 625 tons. Repairs to the lining, which is still in good condition, have been confined to patching at the stock line, the furnace equipment however is worn out. The furnace will be relined and the hearth diameter increased from 18 ft. to 19 ft. 6 in., and a new electric hoisting engine installed to replace the steam operated hoist.

* * *

John B. Tinnon has been appointed manager of sales of the thermit department of the Metal & Thermit Corporation, effective August 1, succeeding W. R. Hulbert. Mr. Tinnon has been connected with the Metal & Thermit Corporation as manager of the rail welding department since 1924.

H. B. Dempsey and Commander H. T. Dyer recently formed the Dempsey Furnace Company, Inc., 110 East Forty-second Street, New York, to design, manufacture and erect industrial furnaces. This line had formerly been produced by the old Dempsey Furnace Company, which since August, 1925, has been operated as the Dempsey Furnace Division of the W. N. Best Corporation. All assets of the old company have been acquired by the new company. Mr. Dempsey will be president of the new company and Mr. Dyer, vice president. The latter was formerly chief engineer of the Peabody Engineering Corporation.

* * *

Adrian blast furnace of the Punxsutawney Furnace Company at Dubois, Pa., has been relighted recently.

COMING MEETINGS

Sept. 10-11—American Manganese Producers Association. First annual meeting at the Mayflower Hotel Washington, D. C. J. Carson Adkerson, president.

* * *

Sept. 17-20—American Society of Mechanical Engineers, second national fuels meeting at Cleveland Ohio. Calvin W. Rice, secretary, 29 W. Thirty-ninth Street, New York City.

* * *

Sept. 24-Oct. 6—World Power Conference, Fuel Conference at the Imperial Institute, London. The Secretaries, 36 Kingsway, London W. C. 2, Englan

* * *

Oct. 1-5—National Safety Council, seventeenth annual safety congress at New York City. Idabelle Stevenson, executive secretary, 1 Park Avenue. Ne York City.

* * *

Oct. 8-12—American Society for Steel Treating tenth annual convention and national metal exposition at Philadelphia. W. H. Eisenman, secretary, 7016 Euclid Avenue, Cleveland, Ohio.

* * *

Oct. 8-12—American Welding Society, annual fall meeting, Philadelphia. M. M. Kelley, secretary 3 West Thirty-ninth Street, New York City.

* * *

Oct. 8-12—Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers, annual fall meeting, Philadelphia. W. M Corse, secretary, 810 Eighteenth Street, N. W., Washington, D. C.

* * *

Oct. 8-12—American Gas Association, annual meeting, Atlantic City. N. J. Kurwin R. Boyes, secretary, 420 Lexington Avenue, New York.

* * *

Oct. 11-13—American Gear Manufacturers' Association. Semi-annual meeting, Statler Hotel, Buffalo. T. W. Owen, secretary, 3608 Euclid Avenue, Cleveland.

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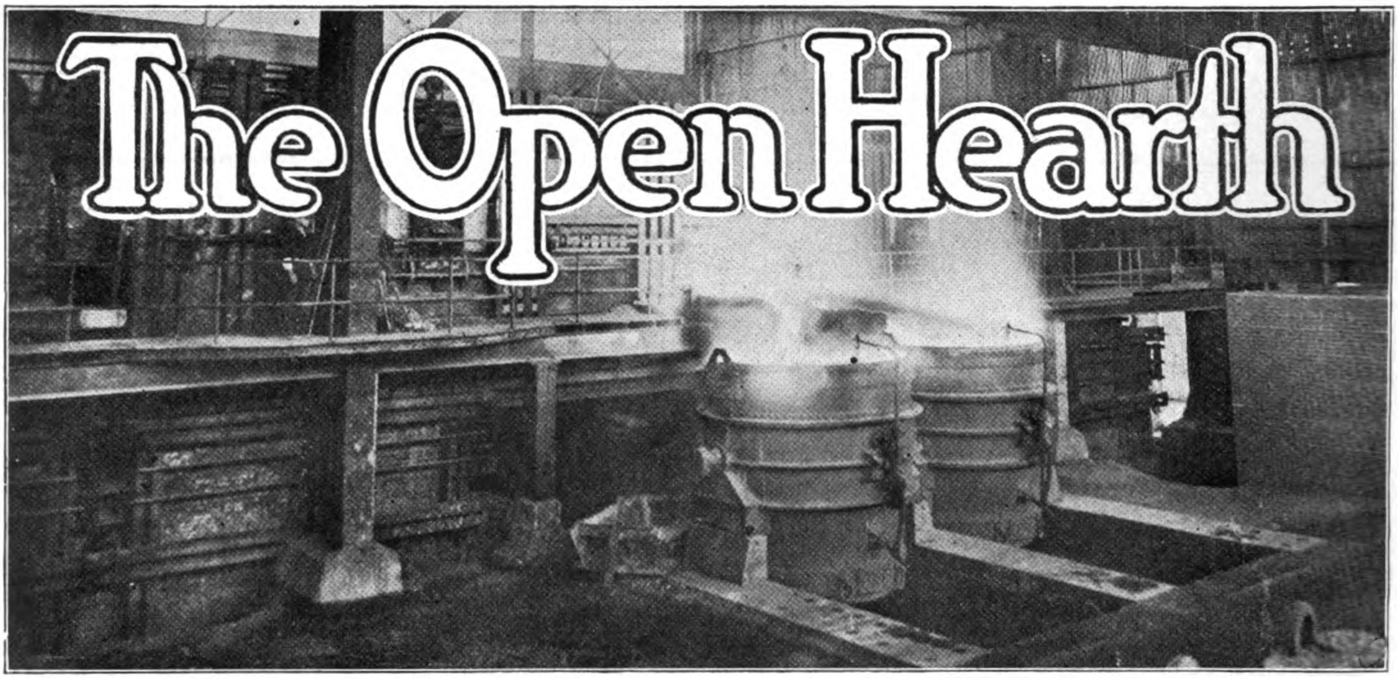
The Open Hearth



W. A. Maxwell, Jr. has been elected vice president of the Colorado Fuel & Iron Company, Denver, and as vice president and production manager will have charge of all manufacturing, mining and related activities of the company. Mr. Maxwell also was elected vice president of the subsidiary companies, the Rocky Mountain Coal & Iron Company, Colorado Supply Company, and the Colorado Realty Holding Company. Mr. Maxwell was associated with the Inland Steel Company as general superintendent of the Inland Harbor, Ind., works, and left that place to become production manager of the Colorado company. Prior to his connection with the Inland company, he had been assistant general superintendent of the Midvale Steel & Ordnance Company, Johnstown, Pa.

* * *

Grant Thorn recently resigned as sales manager of the American Cyanamid Company to become associated with the subsidiaries of International Combustion Engineering Corporation, New York, which are identified with the coal tar products and allied chemical fields.

* * *

C. W. Nixon, superintendent of the Bessemer, Ala., plant of the Central Foundry Company, has been made assistant general manager of all the company's Southern plants.

* * *

Thomas W. Hardy, for five years chief metallurgist of the Timken Roller Bearing Company, Canton, Ohio, has resigned to become metallurgical engineer in the Department of Mines, Ottawa, Canada.

* * *

Joseph Thompson has been appointed works manager of the Standard Steel Car Company, Hammond, Ill., succeeding the late Emil Eiselt. James H. Ryan has been selected as assistant works manager.

* * *

A. G. Williams, formerly sales agent of the Bethlehem Steel Company, Bethlehem district, has been appointed manager of structural and plate sales at Pittsburgh, Pa.

Alfred B. Scott is appointed structural and plate sales agent of the Bethlehem Steel Company, Bethlehem district, located at Bethlehem, Pa.

* * *

Henry S. Baker has been appointed manager of cold-rolled strip sales of the Sharon Steel Hoop Company, Sharon, Pa.

* * *

Joseph Becker has been appointed vice president and general manager of The Koppers Construction Company. He has for some time been vice president and consulting engineer of the company. Mr. Becker is well known in by-product coking circles as the inventer of the "Becker" oven. He has spent 25 years in the by-product coking industry, having started in the laboratories of Dr. Koppers in Essen. He came to this country with Dr. Koppers in 1910 and has been associated with every installation of Koppers ovens in the United States and Canada.

* * *

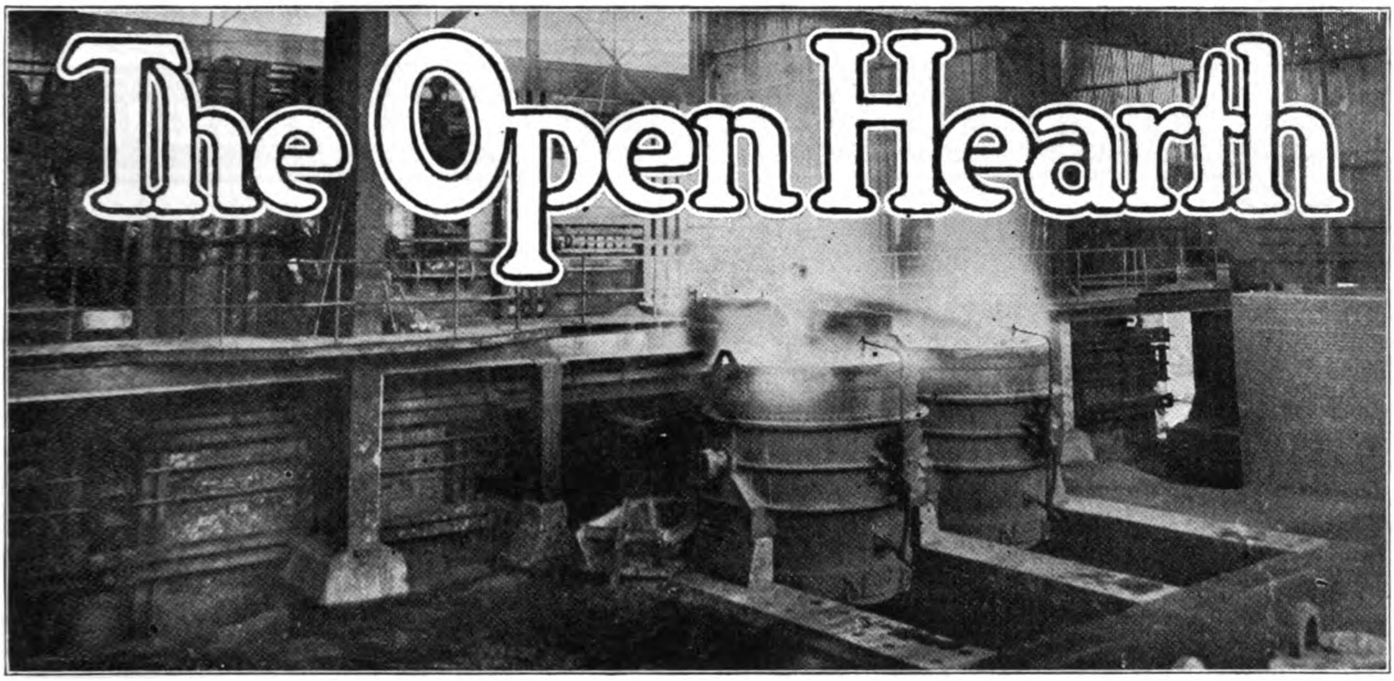
Mr. W. E. Griffiths has become associated with The Duraloy Company of Pittsburgh, as metallurgical engineer. Mr. Griffiths is a graduate of Ohio State University and for a number of years has been a research metallurgist with the Union Carbide and Carbon Research Laboratory at Long Island City.

* * *

Mr. A. F. Morris, former vice president and sales manager, was made president of the Morgan Engineering Company of Alliance, Ohio. Mr. S. F. Kallenbaugh, who has been with the company about 30 years and for the past few years has been assistant sales manager, has been made sales manager, and Mr. Tom J. Muir, who has been with the company about 26 years and who for the past few years has been sales office manager, has been made assistant sales manager.

* * *

Joseph H. Dillon, formerly chief engineer at the Coatesville, Pa., plant of the Bethlehem Steel Company, has been appointed assistant chief engineer at the Wisconsin Steel Works, International Harvester Company, South Chicago.



The Open Hearth

Frank W. Cramer, assistant superintendent of the electrical department of the Cambria plant of the Bethlehem Steel Corporation, has resigned to accept the position of chief electrical engineer of the Republic Iron & Steel Company, Youngstown, Ohio. Mr. Cramer has been connected with the Cambria plant of Bethlehem since 1917. Mr. Cramer has been active in the Association of Iron and Steel Electrical Engineers, at present holding the office of first vice president. He formerly was secretary of the organization.

* * *

L. E. Griffith has been appointed to succeed Mr. William Pestell as sales manager of the Riley Stoker Corporation. At the time the Riley Stoker Corporation purchased the United Machine and Manufacturing Company, who manufactured the Harrington stoker, Mr. Griffith was president of the latter company. Since that time, Mr. Griffith has been district manager of the New York office of the Riley Stoker Corporation.

Mr. W. L. Schultz, who for the past few years has been sales representative of the New York office of the Riley Stoker Corporation has been appointed district manager of that office to succeed Mr. Griffith.

* * *

A. E. Herzberg, manager of transformer sales division of the Wagner Electric Corporation, was promoted on August 3, 1928, from the grade of major of the United States Army Reserve, to the grade of lieutenant-colonel.

Colonel Herzberg's promotion is the latest of a series of continuous and rapid promotions, starting with his original commission as first lieutenant just before our country entered the World war, and raising him through the grades of captain and major.

* * *

Mr. P. S. Menough has recently joined the organization of the Duraloy Company, of Pittsburgh, Pa., as assistant to the president. Mr. Menough is a graduate of Cornell University, and was for nine years chief engineer with the Eastern Malleable Iron Company of Bridgeport, Conn.

V. A. Jevon, who has had charge of the Pittsburgh district for the Bethlehem Steel Company since 1919, has been appointed manager of structural and plate sales at Chicago, Ill., succeeding Lee Hillard assigned to other duties.

Waldemar Dyrssen Dead

Waldemar Dyrssen was born at Stockholm, Sweden, in 1886. Graduated from the Royal Technical University, Stockholm, as metallurgical engineer in 1908. Was for one year (1909) with Les Petits Fils de Francois de Wendel et Cie, Alsace Lorraine as designing engineer in department of construction; three years (1910-1912) with Uddeholm Company, Sweden, as blast furnace and open hearth superintendent; two and one-half years (1913-1915) with the Bethlehem Steel Company, Bethlehem, Pa., as designing engineer in the department of construction; with the United States Steel Corporation, 71 Broadway, New York City, as metallurgical engineer, 1915-1924.

During his employment in the steel corporation he took part in the development of the Heroult electric furnace and metallurgical matters in general under the late W. R. Walker and Mr. J. H. Gray. In 1923 he presented a paper on "Gas Producer Practice in Steel Works" before the American Iron and Steel Institute, New York City and in 1924 a paper on "The Recovery of Waste Heat in Open Hearth Practice" before the British Iron & Steel Institute in London, England. Since 1924 to the date of his death, August 4, 1928, he was with the Blaw-Knox Company, Pittsburgh, as chief engineer, Furnace Equipment Department.

THE STEEL PLANT ROLL TURNER AND DESIGNER

Twenty-Seven Years' Service

Charles Jacob Burns

Charles Jacob Burns has completed over a quarter of a century of service with The Carpenter Steel Company. Beginning as a tool grinder he has worked his way through successive stages until his appointment as superintendent of the roll shop. Today Mr. Burns enjoys an enviable reputation as a roll designer.

Slow Rolling in Smooth Rolls*

The varied composition of alloy steels imposes on the rolling mill crew the definite routine of rolling from predetermined temperatures. The rate of conductivity is low and the heating time is long. Experienced optical pyrometer operators furnish temperatures to heaters, both at pits and at bar mill furnaces. Specified time temperature cycles are furnished the heaters with the rolling order. These are checked, and the 400 deg. F. variation encountered daily in the various special alloy rolling is indicated to the heaters. This method has found favor with the heater, since it insures him assistance in establishing himself without watching each lot during the rolling in order to judge temperature.

Smooth blooming-mill rolls are essential. Reductions are lighter by half due to both lack of ability to bite the ingot and for the protection of the material.

The preliminary working breaks up the ingot structure, and the subsequent rolling can be carried out under nearly normal commercial rolling practice. The skin of the ingot is sensitive, and when it is broken the rupture has not tendency to heal. Every break in the surface means a defect to be removed from the billet by chipping or grinding.

On the whole, the most serious problem in the rolling mills is the wide variation of sizes that must be produced, and the extremely small average quantity. The average tonnage order of alloy steel is less than 10 tons. This entails a multitude of roll changes. The small average size of an order, coupled with the wide variations of characteristics, entails considerable scrap loss in starting orders.

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*From a paper presented by E. C. Smith, American Iron and Steel Institute, New York, May 25, 1928.

Eliminating Most of the Crown†

When the first cluster mill was installed at Huntington, in the early part of 1923, we assumed that it would be necessary to crown the working rolls. We started that mill with the one roll straight and the other one crowned. The backing-up rolls were all straight cylinders. We soon found that we did not need so much crowning, and this has been reduced gradually until the present practice uses very little crowning.

This question of shaping the rolls is becoming of less importance every day. Our practice now is to ship the mills from our shops with rolls ground perfectly straight. Whether crowning of the rolls is necessary or not seems to depend a good deal upon the product to be rolled. With the use of roller bearings, which eliminate the heat produced by neck friction, the swelling of the rolls at their ends due to increased temperature is being eliminated. This in turn has a tendency to do away with the old practice of shaping the rolls.

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†From a paper read at the Youngstown meeting of the Iron and Steel Section of the American Society of Mechanical Engineers by Lloyd Jones.

Bert A. Mick

Bert A. Mick has resigned as manager of roll sales at the Hubbard Steel Foundry Company. He has served the rolling mill industry for the past 31 years. Mr. Mick was connected with the Mesta Machine Company, and the Passaic Steel Company, prior to his work at the Hubbard Steel Foundry Company.

Dan Lewis

Dan Lewis has been appointed Pittsburgh district manager for the Hubbard Steel Foundry Company, East Chicago, Ind., with offices in the Oliver Building, Pittsburgh. He succeeds Bert A. Mick, recently resigned. Mr. Lewis formerly was sales manager and later general superintendent of the Pittsburgh Rolls Corporation.

THE STEEL PLANT BRICK MASON

Blast Furnace Lining Gives Long Service

A continuous operation of nearly nine years during which time the furnace had not been cold, very minor repairs to the refractories being necessary, is the record of the "A" stack of the Toledo Furnace Company at Toledo, Ohio. When the furnace was blown out for rebuilding, it was estimated that the lining should have been good for more than a year longer. The pig iron produced on the lining was 1,835,000 tons and the rate of production during the last year in operation was 625 tons per day. The refractory was furnished by the Niles Firebrick Company.

New Company Organized

The Valley Fire Clay Works, Inc., New Cumberland, W. Va., has been organized with a capital of $180,000, to operate fire clay mining properties and manufacture refractories. The new company is headed by E. H. Miller and Charles Bitzer, Jr., 3155 Penn Avenue, Pittsburgh, Pa.

To Vote on Stock

The Harbison-Walker Refractories Company, Pittsburgh, Pa., will hold a stockholders meeting on September 17 where votes will be taken to change the authorized common stock from 360,000 shares at $100 par value (all outstanding) to 1,440,000 shares of no par value, each present share to be exchanged for four new shares.

Refractory Plant Under Way in Canada

The Ontario Refractories Company, Ltd., Montreal, Que., has begun the construction of its proposed new plant at Amagari, Fort Erie, Ont., where tract of land was recently secured. The works will consist of a group of buildings, and is expected to cost more than $40,000, with equipment. It is understood that the plant will be developed as the main unit of the company and that initial facilities will be increased at a later date.

Plans New Plant

Plans for the construction of a $1,000,000 refractories plant at Augusta, Ga., are being made by the Babcock & Wilcox Company, New York. A new company will be formed to be known as the Babcock & Wilcox Refractories Company.

James Cooper is superintendent of masons for Carnegie Steel Company, at Youngstown, Ohio. He has been with the company for thirty-eight years.

Fire Brick Properties Acquired

The plant and properties of the Andrew Ramsay Company, Mount Savage, Md., manufacturer of fire brick and other refractories, has been secured at a trustee's sale by Townsend Scott & Sons, Baltimore, Md., bankers. The acquisition includes both plant and fire clay deposits at Mount Savage and Ellerslie, Allegany County. It is understood that the new owner will place the property on the market for resale.

Thompson Fire Brick

Papers have been filed with the secretary of state amending the articles of incorporation of the Thompson Fire Brick Company of Radcliffe, Ohio, by making an issue of 1,000 shares of no par value common stock and 750 shares of preferred stock with par value of $100.

Constitution of Refractories

Refractory materials consist essentially of crystals held compactly together by a glassy cement. On this account, therefore, the nature, size, and shape of the crystals, as well as the character and amount of glassy cement, must be factors of first importance. In the case of natural refractories, such as silica and clay materials, there are always inevitably a number of air pores present, and the properties are considerably modified by the nature and number of these voids. These voids are often a source of much trouble, and the chief feature of a cast refractory is that it has practically no porosity, and this is frequently a highly desirable property. But apart from this, all the mentioned groups of refractories are characterized by the presence of numerous crystals, of one or more types, in a glassy matrix.

Modern metallurgy is based to a large extent on the study of temperature-property curves of alloys, combined with microscopical examination of the structural changes involved in defined heat treatments. In a similar manner much of the knowledge of refractory complexes depends on the use of the microscope in conjunction with a study of temperature-property characteristics. By the aid of the petrological microscope it is possible to examine either thin sections or powdered samples of refractory materials, and by so doing valuable information can be obtained concerning the identity and distribution of the crystals. The amount of cementing glass can also be ascertained, as well as the presence of undesirable impurities. In addition to transmitted light examination, it is often desirable to study polished and etched surfaces of refractories by reflected light in order that the size, shape, and orientation of the crystalline constituents in the matrix may be accurately understood. In cases where there are known constituents reflected light examination often provides a rapid and convenient method for studying the microstructure of the material.

World Power.

A Non-Technical Description of Spalling Action

In general, there are two major causes for the destruction of refractories in furnaces. These conditions, which are so common, are more serious than all the other destructive forces combined. If spalling and slag action were not encountered, problems with refractories would be comparatively simple. Furthermore, they are most difficult to combat, by reason of their obscure and complicated manner of occurrence. Their presence is always apparent, but the analysis and detailed explanation of how they proceed and how to prevent their action require careful consideration.

Spalling action has been divided into three subdivisions. They have recently been incorporated in the American Society for Testing Materials' definition for spalling, which reads as follows:

"Breaking or cracking of refractories to such an extent that fragments are separated, presenting newly exposed surfaces of the residual mass.

"The causes of spalling may be classified under three main headings: (1) thermal, (2) mechanical, and (3) structural.

THERMAL SPALLING

Factors Related

To Service	To Refractories
Rapidity and range of thermal fluctuation; contamination by slags and fluxes; tightness of joints; previous vitrification.	Degree and uniformity of reversible thermal expansion; heat transfer; elasticity; plastic flow.

MECHANICAL SPALLING

Factors Related

To Service	To Refractories
Rapid heating of wet brick; abuse in removing clinker and slag; unequal and excessive stresses; pinching.	Mechanical strength; toughness.

STRUCTURAL SPALLING

Factors Related

To Service	To Refractories
Slags and fluxes; character of the material in joints; insulation of refractories; no provision for expansion; thin joints.	Vitrification, shrinkage; nature of bond; structure; degree of firing; accuracy of shape.

Such a division of this subject is desirable from both the practical and theoretical viewpoints. The corrective measure for one type of spalling may not be suitable for the others. Often times the cure may be furnace design or operation, while in another type the answer is a more suitable grade of brick. From the experimental angle the division simplifies a difficult problem.

Mechanical Spalling

The most simple division in the three is that of mechanical spalling. Under this heading there are included the purely mechanical questions which will be noted. In most instances they can be overcome or corrected with due attention to furnace design and operation. For example, brick are often set in a wet condition and require considerable time to be thoroughly dried. If they are heated too rapidly while wet there is real danger in the formation of steam under pressure within the pores which will expand and weaken or crack the brick.

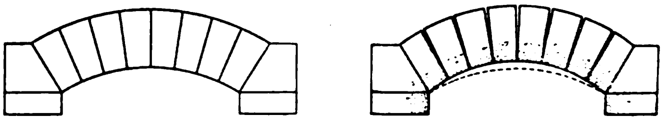

FIG. 1—An arch when cold and while hot. Shaded portion indicates heated area of brick. Note dotted line which was the original position of the arch.

A very common cause of mechanical spalling is that called "pinching." The pinching is caused by the pressure exerted when the brick expand during heating. Refractories, like other materials, expand when heated. If the portions of the brick which are heated are not free to expand, a tremendous pressure will build up. This pressure will readily break off the ends of brick to relieve the strain. It is sufficient to cause arches to raise and has been known to cause very serious damage in large furnaces. The diagram of Fig. 1 shows what happens when an arch expands. The increased pressure on the inner ends of the brick often causes a few brick or even a layer to be pinched off. In laying up an arch it is better to have the outer rather than the inner ends of the arch brick to fit close. Warped and untrue brick are quite certain to spall, especially when laid up dry in an arch. This is not so apt to happen on imperfect brick when a mortar is used to take care of inequalities.

In side wall construction a good plan is to insert in the joints at intervals the necessary thickness of cardboard, which will burn out leaving a space for expansion. The space necessary for the brick to expand may be figured from the coefficient of expansion of the brick in question. For example, suppose the coefficient is .000006 (which means that a unit of length will expand .000006 part of its length for each deg. C.); then at 1000 deg. C. the expansion would be $.000006 \times 1000$ deg. C. $= .006$ of the length. For a section of wall 10 ft. long, the linear expansion would be $.006 \times 10$ ft. $= .06$ ft. or about ¾ in. Part of this expansion would be taken up in the joints between the brick, so that provision is only necessary for a portion of the actual expansion.

Structural Spalling

The heading of "structural spalling" intends to cover a type of action which is not generally known or considered. Most refractory materials undergo a marked change in their structural or physical properties after prolonged use. After long exposures to high temperature and slags or fluxes the brick invariably become vitrified to a degree. Accompanying this vitrification there is usually a permanent change in the dimension of the exposed portions. If the expansion or contraction, as it may be, is excessive, there will be a tendency toward a separation between the original and the heat treated portions. This is shown in Fig. 2. There are a number of properties upon which depends the seriousness of this action. The expansion or shrinkage may proceed to a considerable degree without any evidence of separation. A gradual transition from the altered to the unaltered portions will reduce the tendency toward cracking or separating. Pronounced shrinkage of a given section is very apt to cause the severing of the dissimilar portions.

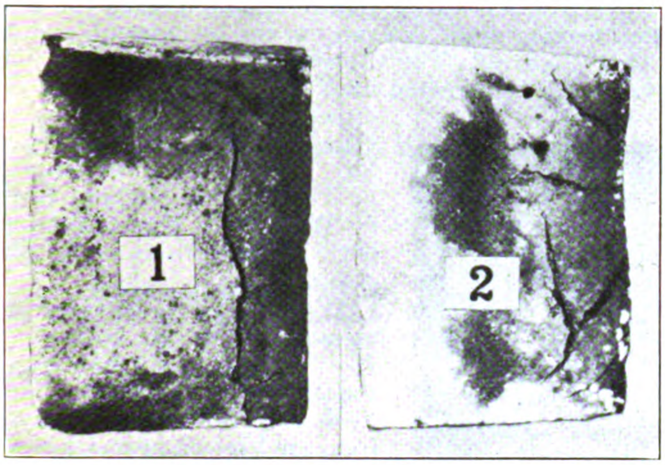

FIG. 2—Kiln liners taken from service, which show the progress of structural spalling. These shrinkage cracks would soon lead to a serious spalling condition.

It is often exceedingly difficult to distinguish between this type of spalling and that produced by thermal shock. Studies of the behavior of various types of clay refractories indicate that the structural causes play a very important part in most conditions of spalling. Many grades of clay brick are known to spall more rapidly from this cause than from that of pure thermal shock.

Differentiation between the structural and thermal spalling is very necessary because the means of correcting each type are dissimilar. This is especially true in view of the common occurrence of the structural, which is mistaken for the thermal type.

Shrinkage is the main cause of this spalling; therefore, conditions such as slagging or fluxing which may be present within the furnace will hasten the action. Unnecessarily high temperature in some operations results from the insulation of the walls, which is conducive to shrinkage or spalling. Open joints, caused by shrinkage or the melting away of unsatisfactory mortar, are serious because they allow the heat to come in contact with a larger area of the brick, thereby heating the face to a greater depth and to a higher temperature.

Thermal spalling, which is due to rapid temperature changes, is the type most commonly thought of. In a number of kinds of refractories, for example, silica, chrome and magnesite, it is the all important variety. It is the most difficult to prevent from the producer's point of view, since it is caused by certain properties of the brick which are exceedingly difficult to alter.

As previously mentioned, brick expand when heated and likewise contract when cooled. A brick is a rigid body and in order to conform to the increased size of an expanded portion, several conditions must be met. For example, in Fig. 3 the heated end could not have assumed its shape and still have been part of the brick unless certain portions were elastic or plastic. If the brick did not possess properties which would allow such a change in dimension, the heated or expanded section would crack away from the remainder as is shown in Fig. 3-B. This often happens in refractories which spall by thermal shock.

The property of plastic flow, such as tar exhibits, would allow a rearrangement of the brick structure so as to conform with the effects of rapid heating and cooling, thus preventing spalling. Clay brick have been studied to learn of the presence of these properties and it has been shown that they are elastic up to about 800 deg. C. and at higher temperatures they show the plastic flow.

Another factor is that of the thermal conductivity of the brick. One having a high rate of heat flow would not allow as great a difference in temperature to exist between sections as one of lesser efficiency. The brick shown in Fig. 3-C and D show these conditions.

There does not appear to be much that can be done to materially increase the thermal spalling resistance of most brick. Soft firing and an open structure help in certain kinds of service. A careful selection of raw materials is often of assistance. The blending of clays having approximately the same thermal expansion is to be favored over those which show appreciable difference in their coefficients. Open burning clays are more desirable than those which readily vitrify, especially in the case of the plastic or bond clay. Coarse, splintery particles for grog are advantageous.

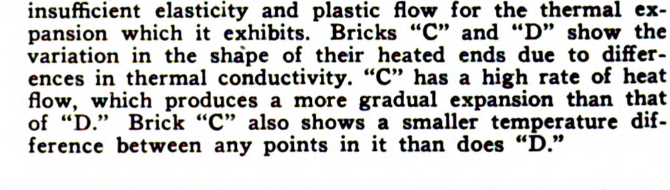

FIG. 3—Shaded portions indicate presence of heat. "A" shows expansion of the end due to heat. The elasticity and plastic flow allow the heated end to assume such a shape without cracking. In brick "B" spalling has taken place because of insufficient elasticity and plastic flow for the thermal expansion which it exhibits. Bricks "C" and "D" show the variation in the shape of their heated ends due to differences in thermal conductivity. "C" has a high rate of heat flow, which produces a more gradual expansion than that of "D." Brick "C" also shows a smaller temperature difference between any points in it than does "D."

—Abstract from Bulletin 24 by Stuart M. Phelps, director of Research and Tests, American Refractories Institute.

SAFETY FIRST IN THE STEEL PLANT

325 Speakers to Address Safety Meet

Five hotels will be required to house the 110 meetings, 325 speakers and 6,000 persons expected at the Seventeenth Annual Safety Congress, which will be held at New York City, October 1-5 inclusive, when the question of how to check accidents on the streets and highways, in other public places, at home and throughout industry will be considered.

Meetings will be held in the Hotels Pennsylvania, Waldorf-Astoria, McAlpin, Martinique and Commodore. There will be no charge for admission and non-members of the National Safety Council also will be welcome to attend the various sessions. The final program will be circulated at the convention.

The annual banquet, which is always one of the numerous features of the national safety congress, will be held at the Commodore Hotel, New York City, on Wednesday evening, October 3. The names of the speakers and the subjects they will discuss will be announced in the final edition of the program.

G. H. McClain is safety engineer at the South Side Works of the Jones & Laughlin Steel Corporation, at Pittsburgh, Pa., having occupied that post for the past five years. Mr. McClain has been engaged in safety first work for twelve years.

Safety Work Brings Good Results

Members of the National SafetyCouncil are reducing the number of industrial fatalities in their shops and factories as shown in the annual statistical compilation, just made public, comprising a pamphlet covering the safety experiences of some 2,089 establishments in varied lines.

One of the most interesting facts brought out in the statement is that 133 establishments, or 7 per cent of the total, completed the year of 1927 without one lost time injury. Represented in this group are 8 automotive, 12 chemical, 29 food, 13 metals, 3 packers and tanners, 14 paper and pulp, 8 power press, 15 public utilities, 2 quarry, 4 textile, 10 wood-working and lumber manufacturing and 15 miscellaneous.

Another interesting fact is that the 1927 average accident severity rate equals 1.88, while the average for two years previous equals 2.50—a reduction of 24 per cent.

The ratio of persons employed to lost time injuries is 16 to 1. Days lost per injury equals 71. The ratio for two years previous equals 12 to 1, with 73 days lost per injury. The 1927 average accident frequency rate equals 25.95. The average for two years previous equals 31.31; a reduction of 17 per cent.

Metals Section

Members of the National Safety Council's Metals Section will get together at a roll call luncheon, which will be held on October 1, in the Waldorf-Astoria Hotel, New York City, immediately following the general meeting of the delegates to the seventeenth annual safety congress. The community singing at the luncheon will be directed by N. V. B. Zeigler, personnel director of the U. S. Aluminum Company, New Kensington, Pa. There will be an address by Dr. Charles Herbert Rust, of Worcester, Mass., and reports of the various committee chairmen.

At the morning meeting on October 2, R. M. Roosevelt, vice president of the Eagle Picher Lead Company, New York City, will discuss "Safety from the Viewpoint of Management." Dominic Samuels, foreman, Youngstown Sheet & Tube Company, Youngstown, Ohio, will lead a discussion of "Safety from the Viewpoint of Supervision."

Nelson H. Keyser, safety engineer, the Studebaker Corporation of American, South Bend, Ind., is to speak on "The Correction of Unsafe Practices in Foundries," at the morning session on October 3. Following the election of officers, L. A. Hartley, director, educational department, National Founders' Association, will lead a discussion on "Developing a Safe Human Factor in Our Industries," and A. W. Colcord, M.D., plant surgeon, Clairton Works, Carnegie Steel Company, Clairton, Pa., will start a discussion on "The Placement of Men, or What the Surgeon Can Do."

Dr. L. W. Chaney, U. S. Bureau of Labor Statistics, Washington, will discuss "A Review of Accidents and Progress in the Steel Industry," at the morning meeting on October 4. There will be a debate "That the Foreman Is Responsible for Accidents that Occur in His Department," in which J. A. Voss, of the Central Alloy Steel Company, and Mike Grady, president, Stark County Foreman's Club, Canton, Ohio, will participate. John A. Oartel, chief of safety bureau, Carnegie Steel Company, Pittsburgh, will present some timely lantern slides.

Did You Know that—

According to the annual statistical compilation of the National Safety Council, the ratio of non-fatal to fatal injuries for 1927 equals 155 to 1; the ratio for two years previous equals 154 to 1?